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OCTOBER, 1939

STRUCTURAL GEOLOGY OF WIND RIVER CANYON AREA, WYOMING[1]

JOHN R. FANSHAWE[2]
Camp Crook, South Dakota

ABSTRACT

The Wind River Canyon of Wyoming provides a structural cross section of the Owl Creek-Bridger uplift, and gives effective indication of the processes and stages by which Laramide deformation proceeded in this region. Exposures in the canyon area also indicate the rôles of competency variations within the stratigraphic column in controlling pressure responses of different rock units. The Laramide faults and folds are in part reflections of these competency variations, and in part owe their trends to the resolution of the applied Laramide deformative forces.

The structure of this canyon area is particularly interesting because of the illustrations it affords of the structural contrasts between the nature and origin of the primary inter-basin Owl Creek-Bridger uplift, and the secondary intra-basin ramp and other basin-mechanics products which feature the Bighorn Basin. The Owl Creek-Bridger uplift was initiated as an anticlinal fold by inter-basin competition early in Laramide deformation; and was subsequently ruptured by southward and slightly eastward crowding of the Bighorn Basin, relative to the Wind River Basin, as deformation progressed. The Boysen fault is a normal one, developed after the southward overthrusting was largely complete, and was due to the (relative) downdropping of the toe of the overthrust mass. Some additional post-Boysen-fault thrusting is also indicated by the drag effects shown south of this fault.

Post-Laramide dips in the adjacent Wind River Basin are interpreted as due to accentuation of initial depositional slopes after compaction under once-present sedimentary overburden.

INTRODUCTION

SCOPE AND PURPOSE OF INVESTIGATION

The Wind River Canyon, which transects the Owl Creek-Bridger uplift, provides an excellent opportunity for studying the nature and origin of intra-basin and inter-basin structures of types that are common in the central Rocky Mountain area. In particular, it is possible to determine relationships between primary inter-basin overthrusting of major proportions, and secondary—or subsidiary—ramp and other basin-mechanics structures which feature intra-basin areas in central and eastern Wyoming.

[1] Manuscript received, June 9, 1939.

[2] State Royalty Petroleum Company.

FIG. 1.—Panoramic view showing dip slopes along north flank of Owl Creek-Bridger uplift, and north portal of Wind River Canyon. Dip-slope is underlain by stripped resistant limestone member in upper part of Phosphoria formation. Red Canyon anticline forms near sky-line on southwest. "Vest-pocket" example of superposition may be seen in left foreground where Buffalo Creek has cut across Buffalo Creek Canyon flexure. Wind River becomes Bighorn River as it flows out of Wind River Canyon in the right middle-distance. High peak on distant left-center sky-line is Boysen Point (Fig. 4). Camera swings from south-southeast to southwest. Compare with Figures 4, 5, and 7.

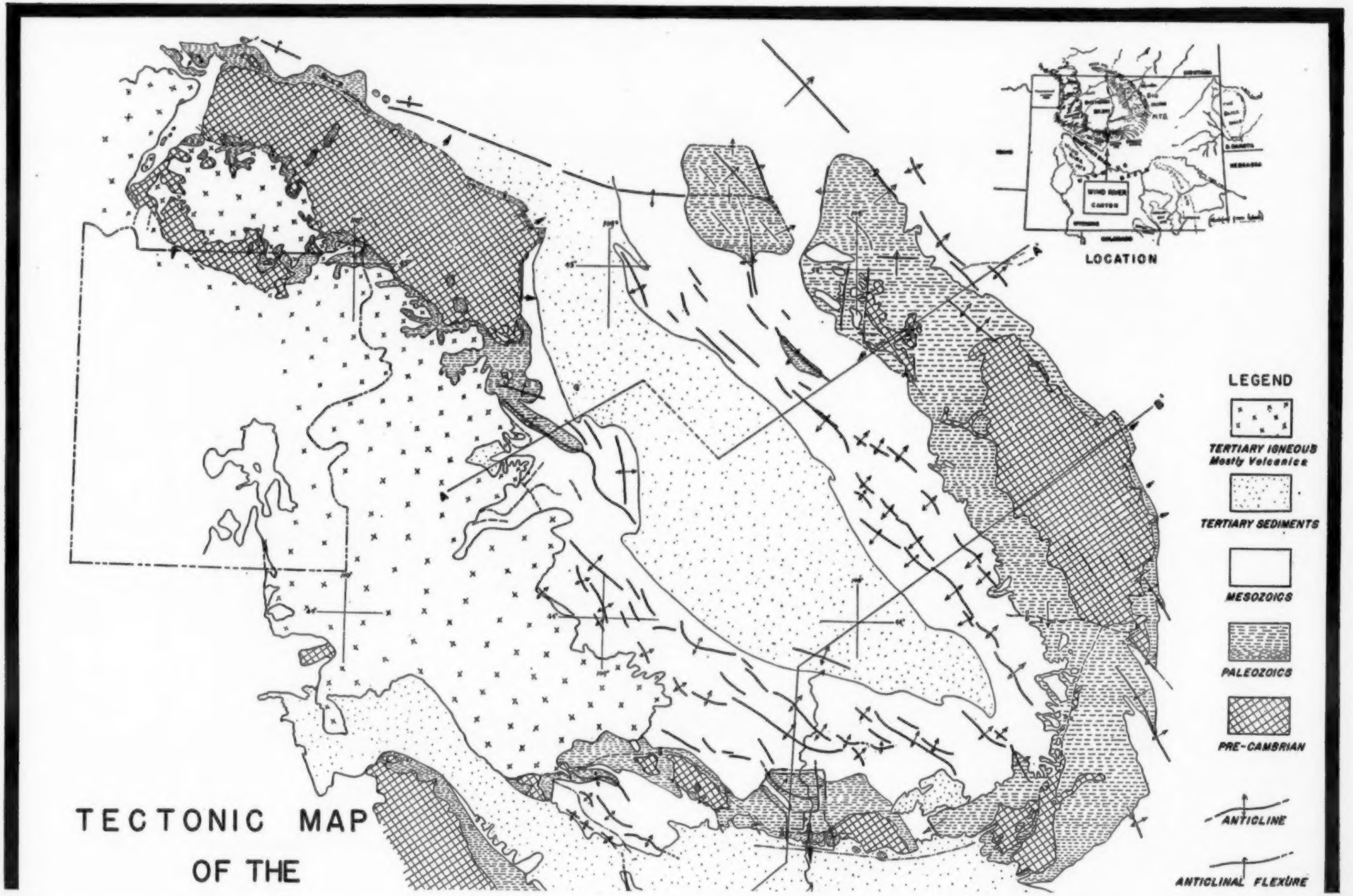
The structural features and relationships dominant in the tectonic pattern of the central Rocky Mountain region are exhibited with exceptional clarity, and on a major scale, within and near the Wind River Canyon. Consequently, the writer's study of structural features and relationships of the general Wind River Canyon area, though undertaken primarily to provide information as to the nature and dynamics-of-origin of these local tectonic features, was also undertaken because such a study of this typical area would ultimately provide an important contribution toward an understanding of the building of the Central Rockies as a whole. To serve both purposes, it was obviously essential to determine, so far as possible: the nature and space relationships of the structural features within the Wind River Canyon area; the evolutionary sequence of tectonic events in the development of those features; and the nature, direction of application, and mode of transmission of the forces which were productive of the deformational features observed. Because of the time limitations within which the work had to be done, attention was centered almost exclusively upon the determination and three-dimensional mapping of the structural features, with only such minimum studies of the stratigraphic and other phases of the geology of the region as were indispensable to the tectonic studies projected.

The magnitude of the features and the position of the area in respect to the other larger features of the Central Rockies make it of prime importance in the eventual resolution and recognition of the forces that were operative during the tectonic development of the mountain systems of the region.

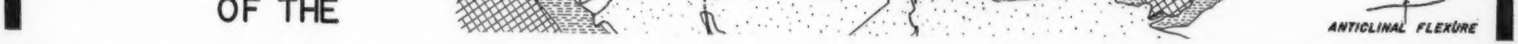
LOCATION AND NATURE OF AREA

As shown by Figure 2, the area chosen by the writer is roughly rectangular—about 17 miles in length (from north to south) and about 8 miles in width.

From north to south the area extends from the Bighorn Basin, across the Owl Creek-Bridger-Bighorn mountain arc, into the Wind River Basin; whereas from west to east it begins 2 miles west of the Wind River Canyon and extends to the Birdseye Pass valley along the western flank of the Bridger uplift. The river flowing northward through the canyon is called the Wind River until it reaches the north portal of the canyon, where it becomes the Bighorn River, and is remarkable for the small number of its permanent stream tributaries. Just east of the canyon lies what is termed "Copper Mountain," which continues into the Bridger uplift, and west of the canyon the name Owl Creek Mountains is applied. The names are of



TECTONIC MAP
OF THE
LOCATION
WIND RIVER CANYON
LEGEND
TERTIARY IGNEOUS
Mostly Volcanics
TERTIARY SEDIMENTS
MESOZOICS
PALEOZOICS
PRE-CAMBRIAN
ANTICLINE
ANTICLINAL FLEXURE



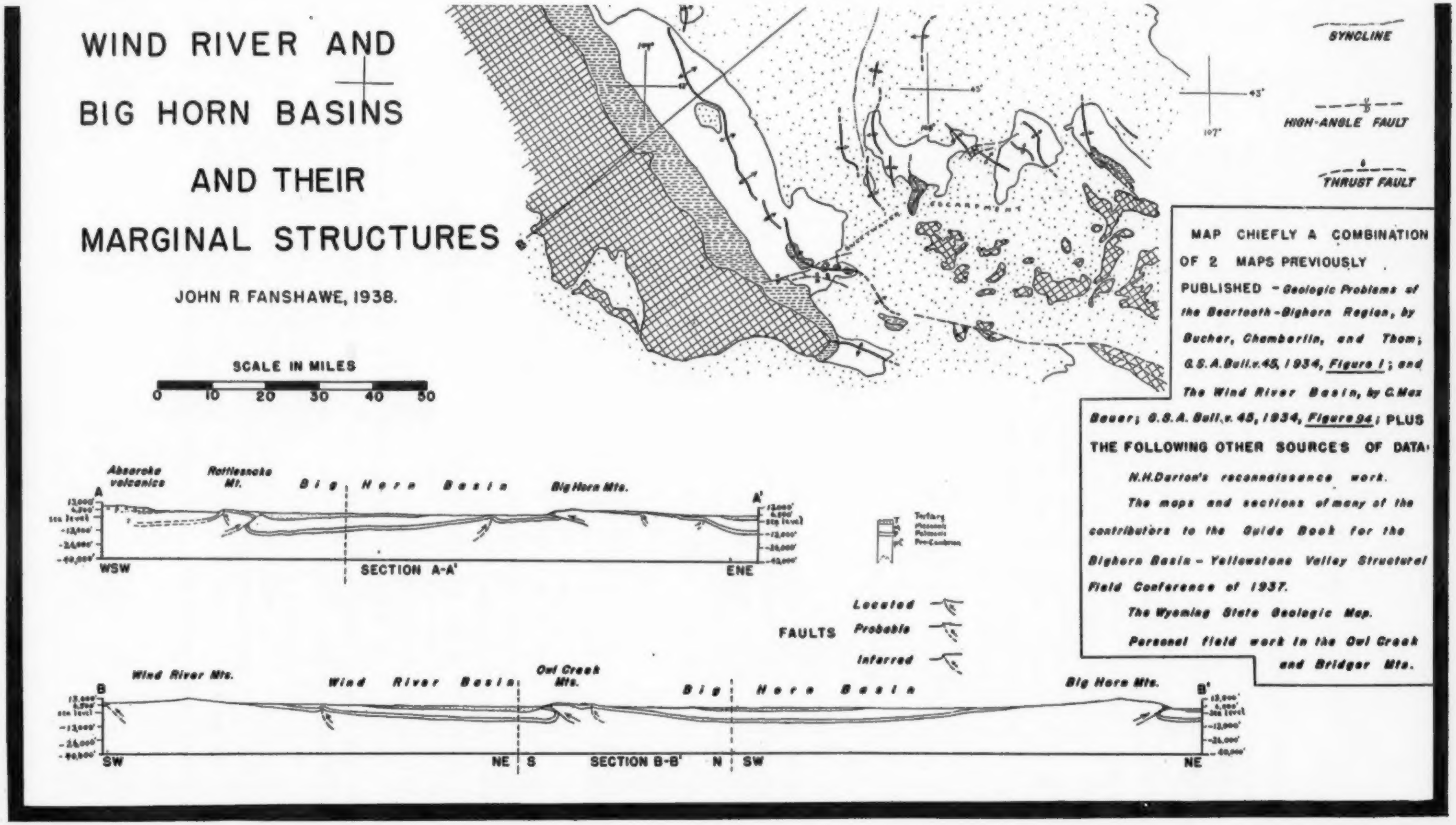


FIG. 2.—Tectonic map of Wind River and Bighorn basins and their marginal structures, with cross sections.

topographic significance only, as the continuity of the structure east and west across the canyon is obvious. At the canyon, the mountain uplift itself is 13 miles across on a north-south line from the Bighorn Basin to the Wind River Basin.

U. S. Highway Route 20 and the Chicago, Burlington, and Quincy Railroad pass through the area, converging to go through the Wind River Canyon. Except for this canyon highway, roads are few and very poor, but make possible an approach by car to within 3 miles of any point in the area.

Topographically the Owl Creek-Bridger range is featured by a series of dip and scarp slopes, the result of the stripping-off of softer sediments from the backs of the more resistant sandstones and limestones by intermittent stream action and sheetwash—aided slightly by the wind during the longer dry seasons. Except for the zone south of the Boysen fault, it is Bighorn Basin topography on a grander scale. The canyon is an erosional cut at right angles to the general east-west strike of the Paleozoic strata. A few pediment remnants of two or more cycles extend outward into the basins from the north and south flanks of the uplift. These surfaces slope away from the mountains, bevel folded and tilted strata, and are characteristically covered with a veneer of coarse boulders and slightly waterworn gravels.

There is no evidence of beveling of the strata at or near the summits of the mountains in the Wind River Canyon area.

REVIEW OF OTHER GEOLOGIC INVESTIGATIONS

Most early geologists avoided the Wind River Canyon. The Bighorn Basin on the north received much attention, as has the Wind River Basin on the south, but the area between has probably been regarded as a barrier that had to be crossed rather than investigated.

The canyon is not mentioned in the reports of Captain John C. Fremont's explorations in 1841.

The Heyden Surveys for 1868 give a short geographic description of the canyon, but the territory on the south, west, and northwest was their main concern (20, p. 71).[3]

In 1894 G. H. Eldridge published the first geologic map of central Wyoming and recognized the anticlinal type of the mountain uplift in the canyon area (16).

N. H. Darton was the first to publish a comprehensive report on the geology of the region in 1906 (14). His work still stands on the present geologic map of the state of Wyoming.

As far as structural geology is concerned, this completes the his-

[3] Numbers in parentheses refer to Bibliography at end of article.

tory of previous field work in the area—except for observations made by Bucher, Chamberlin, and Thom (8, 9) prior to and during the progress of the investigations for this report. Their reconnaissance indicated importance of the Wind River Canyon area in structural interpretations of the Central Rockies; this work was suggested by their regional studies.

C. S. Gwynne has published on the pre-Cambrian structure of the canyon itself (19).

Many workers have paused in or near the canyon area in pursuance of a stratigraphic, physiographic, or regional economic problem, but they have not added materially to knowledge of the tectonic history of the mountains. Some of their works are listed in the appended bibliography.

After the completion of this manuscript an article to refute a supposed theory of ramp origin for the Owl Creek-Bridger uplift was published by C. T. Jones (24) on a part of the area included in this report. From the wording on p. 5 of the 1937 Guide Book for the Bighorn Basin-Yellowstone Valley Field Conference it *can* be inferred that ramp thrusting led to the development of the Owl Creek-Bridger mountain structures; actually, the only structural feature in the area with which a ramp fault in the subjacent basement rocks is postulated is the Red Canyon anticline (Fig. 4). At the final meeting of the field conference in Cody on August 5, 1937, the writer—in a discussion on the Boysen fault—set forth his views on this point, agreeing with John L. Rich when the latter called attention to the improbability of ramp faulting in association with the major structures exposed in the Wind River Canyon.

FIELD WORK

The field work for this paper was done during the summers of 1931, 1935, 1936, and 1937 as a thesis study conducted under the direction of the Department of Geology of Princeton University, and also as a unit in the major research program of the Yellowstone-Bighorn Research Association, whose headquarters are at Red Lodge, Montana.

Lithology was found to be an adequate basis for the correlation of the strata within the region covered by this report. As correlation of the formations with those in near-by described areas was made easy by the previous work of many other observers, fossil collecting and the identification of paleontological specimens were not primary objectives.

The pre-Cambrian rocks have been treated as a complex unit in

these investigations, and no attempt has been made to establish their age relationships to pre-Cambrian formations in other regions.

Lack of any good base map retarded the investigations to the speed of map making. Air photographs became available in 1935 through the activities of the United States Soil Conservation Bureau. Some of these have been used to check the plane-table work.

ACKNOWLEDGMENTS

It is a pleasure to acknowledge indebtedness to Princeton University, where this report was submitted in partial fulfillment of the Ph.D. degree requirements; to members of the Yellowstone-Bighorn Research Association; and to the others who have aided in the direction or excution of this work. In particular, the writer wishes to express his thanks for the help of the following persons: Professors W. T. Thom, Jr., R. T. Chamberlin, and C. W. Wilson for critical assistance in the field and in conference; Professors C. Deiss and C. Lochman for Cambrian stratigraphic and faunal determinations; I. G. Burrell, B. C. Haviland, D. C. Sullivan, S. Seay, H. R. Wardwell, H. L. Ferguson, Jr., E. G. Hoffman, Jr., E. S. Richardson, Jr., E. S. Willing, Jr., and Mrs. John R. Fanshawe for their aid as field assistants; and Mr. and Mrs. Paul Hodgson for their help and hospitality in Thermopolis, Wyoming.

Above all, the writer wishes to record his sincere appreciation for the interest, encouragement, and help of the late Mrs. Jennie M. Arms Sheldon of Deerfield, Massachusetts; this work is dedicated to her memory.

STRATIGRAPHY

GENERAL SUMMARY

As shown by Table I, the section involved in Wind River Canyon structures includes formations from pre-Cambrian to late Eocene in age—minus representatives from the Silurian and Devonian periods. Quaternary (or Tertiary?) gravels, in many places with travertine, cover pediment or bench remnants that slope toward the basins from the lower flanks of the mountain uplift.

The resistant pre-Cambrian rocks are chiefly dense black crystalline schists and brown stratified schists that are intruded by granites. None of the intrusions penetrates into Cambrian or younger formations; all are beveled by the erosion surface that developed before Cambrian deposition was initiated. This unconformity reveals a topography with a local relief of about 50 feet.

TABLE I

STRATIGRAPHIC SECTION FOR WIND RIVER CANYON AREA, WYOMING

Age	Formations	Thicknesses in Feet: Bighorn Basin (Hewett, 22)	Thicknesses in Feet: Canyon	Thicknesses in Feet: Wind River Basin (Bauer, 3)
Eocene	Wind River Wasatch			
Paleocene	Fort Union	2,000 – 5,600		975
Cretaceous(?)	Lance	840 – 1,800		950
Cretaceous	Meeteetse	250 – 1,400		940
	Mesaverde	1,120 – 1,410		980
	Cody	1,900 – 3,400	10,837*	4,200
	Frontier	494 – 648		800
	Mowry	160 – 375		250
	Thermopolis	400 – 800		209
	Cloverly	110 – 300		20
				150
		7,274*–15,733*		40 9,504*
Jurassic	Morrison		305	
	Sundance		325	
Triassic	Chugwater		1,300	
	Dinwoody		60	
				1,990*
Permian	Phosphoria		220	
Pennsylvanian	Tensleep		380	
Mississippian	Amsden		260	
	Madison		450	
Ordovician	Bighorn		140	
Cambrian	Boysen		530	
	Depass		570	
				2,550*
Pre-Cambrian	Schists, gneisses, and granites			

Approximate thickness of section, base Depass to top Fort Union, 15,380.*
Cambrian thicknesses from C. Deiss (15).
* Totals. Figure for Cretaceous and Paleocene of canyon area is estimated.

The Paleozoic depositional record begins with the conglomeratic base of the Depass formation of Middle Cambrian time. Eleven hundred feet of sediments were deposited during the rest of the Cambrian. The Depass formation consists of a basal Flathead facies of quartzites, sandstones, and thin shale lenses, and an upper shale and sandstone Gros Ventre member. The thickness is 530 feet. Upper Cambrian time is represented by the 570 feet thickness of the Boysen formation,

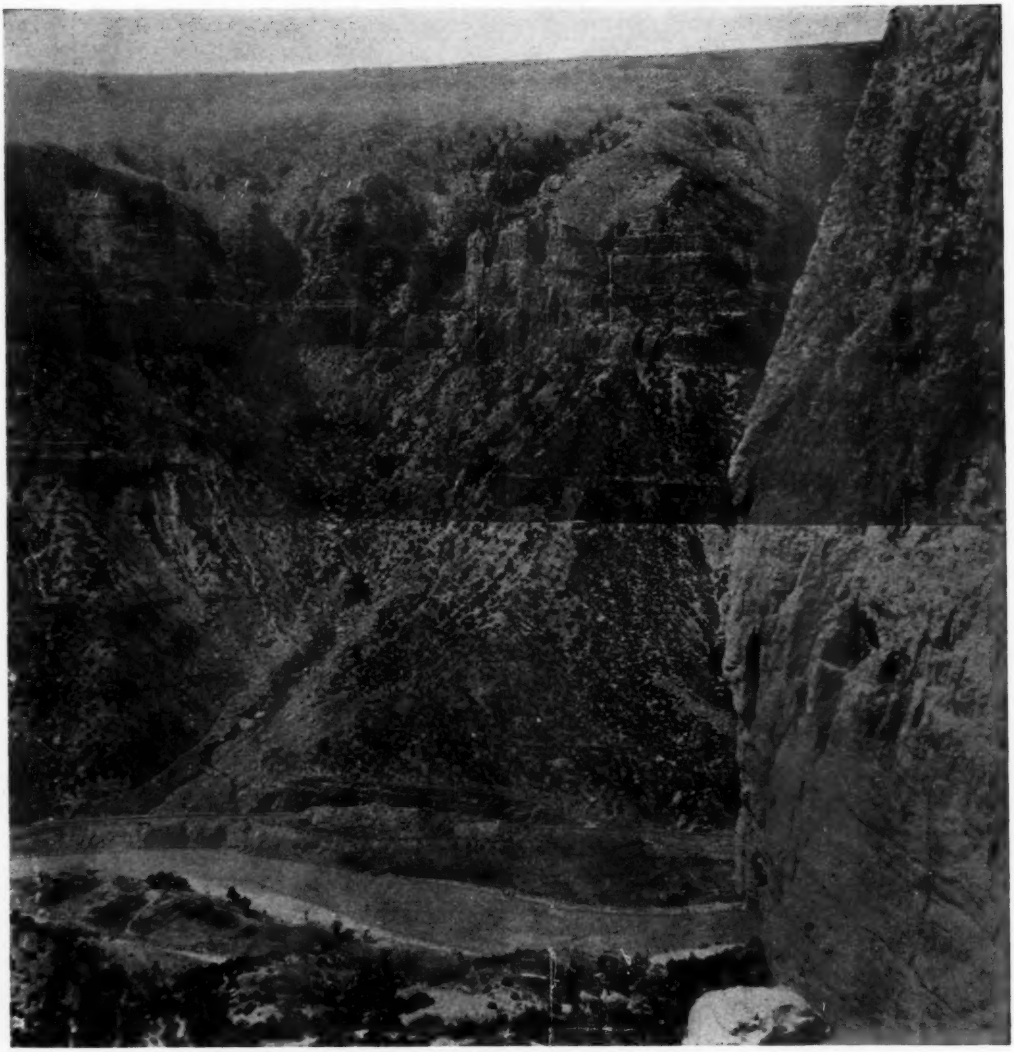


FIG. 3.—View of Paleozoic section, and top of pre-Cambrian, exposed in west wall of Wind River Canyon. Base of Bighorn dolomite is in immediate right foreground.

which is mostly limestones, calcareous shales, and shales, and contains beds of intraformational conglomerates throughout.

This entire Cambrian section was first called "Deadwood" by N. H. Darton in 1906 (14). It was subdivided by B. M. Miller in 1937 (31) who applied the name "Gallatin" to the upper part of the section, and proposed the new formational name of "Depass" for the lower half of the section. Later work by C. Deiss (15) and C. Lochman in 1937 revealed faunal evidence that showed the term "Gallatin" to be ill-advised. These last two investigators have re-delimited Miller's Depass formation, and proposed the new term "Boysen" formation to apply to the Upper Cambrian strata.

Ordovician time is represented by the 140-foot cliff of massive Bighorn dolomite. A basal yellowish sandy zone rests on the purplish beds of the Cambrian, and grades upward into the massive dolomite. A. K. Miller (30) refers all of the Ordovician beds present to the Richmond stage.

The Mississippian Madison limestones, 450 feet thick, overlie the Bighorn formation with no apparent disconformity. Faunal contrasts show the difference in age, but the actual line of contact representing the hiatus is hard to find. The Amsden formation gives the record of the Lower Pennsylvania and the Chester epoch of Upper Mississippian (32); there are 40 feet of purplish shales, ordinarily covered, and 220 feet of limestones and shales interbedded with great quantities of chert. The basal Amsden contact is covered; the contact with the overlying formation is erosional.

Continental sediments, mainly wind-driven sands, form the 380-foot thickness of the massive and cross-bedded Tensleep formation.

Marine conditions become re-established in Permian time and the limestones and shales of the Phosphoria formation were deposited. The gently undulating eroded surface of the Tensleep sandstone is in part the cause for the thickness variations of the basal limestone members.

Triassic formations, 1,360 feet thick, succeed the Phosphoria. The bottom 60 feet of shales and limestone is called the Dinwoody formation, and is here mapped with the Chugwater. The Phosphoria-Dinwoody combination has been termed the Embar group. It is clearly shown by H. D. Thomas (34) that, in this area, the "group" brackets beds that belong in different periods, and that the Dinwoody is a facies, equivalent in age to the base of the Chugwater farther east. Because of this awkward time overlap, the term "Embar" is not used in this report. The Dinwoody formation is followed by the Chugwater formation, consisting of 1,250 feet of shale and sandstone redbeds topped by 50 feet of gypsum.

The disconformity above the Chugwater represents the absence of much record as the overlying Sundance formation belongs in the Upper Jurassic. The lower portions are made up of fine-grained limestones, shales, and a few gypsum layers; the upper portions are mostly greenish sandy shales containing *Gryphaea* and *Belemnites*. The greenish sandstones and sandy shales of the Morrison formation continue the record of Upper Jurassic time. There is no clearly marked line between these formations; together they are 630 feet thick; and, where measured, the Sundance is 305 feet thick—if the arbitrary line of separation was correctly chosen.

The basal conglomeratic beds of the Cloverly formation are disconformable over the Morrison, and begin the Cretaceous record after the lapse of nearly all of Lower Cretaceous time.

Structural complexities and lack of exposures make it impossible to gain information as to the thickness and lithologic character of the represented Upper Cretaceous formations within the Wind River Canyon area, though some beds beneath overthrust Paleozoic rocks on the west side of the river at the south entrance of the Wind River Canyon have been exposed by erosion. Deformation in this area has been so intense (Figs. 5, 6, 15, 19, and 21) as to render measurements useless and the identification of formations uncertain. For information on the thicknesses and characteristics of these sediments the nearest described areas in the Bighorn and Wind River basins have been used (3, 18, 22, 25).

Measurements by Bauer and Hewett in near-by areas (Table I) indicate that 10,000 feet for the entire local Cretaceous section is a probable estimate.

After Bauer (3), the total thickness of Mesozoic sediments present in the part of the Wind River Basin covered by this report should be between 9,000 and 10,000 feet. Deducting the 2,000 feet of Mesozoic section measured in the canyon area, there should remain at least 7,000 feet of Upper Cretaceous sediments, as well as the Fort Union of the Paleocene, that are covered by the overlap of the Wind River formation.

D. F. Hewett (22) gives measurements for these strata in an area that extends to the southern part of the Bighorn Basin about 20 miles west of Thermopolis. From the Cloverly formation (Lakota-Fuson-Dakota of Bauer) up through the Fort Union formation there is a *minimum* thickness of 7,274 feet and a maximum thickness of 15,733 feet.

Shale beds make up the bulk of the Cretaceous section, but sandstone and limestone layers occur at intervals. Coal seams are found in the formations overlying the Cody shale.

Love (26) reports 0–1,500 feet of Wasatch beds overlying deformed undifferentiated Cretaceous formations in the western Owl Creek Mountains.

The Wind River formation of Upper Eocene age (3, 6, 33) is absent from most of the Bighorn Basin, but overlaps all older formations at various places on the south front of the Owl Creek-Bridger uplift. It filled the valleys that resulted from the erosion of the newly formed Laramide Mountains and therefore still extends for a mile or more within the present mountain topography. It is composed chiefly of sandy shales of all colors (grays and buffs predominating), with local fanglomeratic facies against the mountains. The oldest beds of the Wind River formation are not exposed and the upper parts are missing. It is the writer's belief that this formation once covered the mountain area in the vicinity of the Wind River Canyon, as outliers still exist at the headwaters of Bridger Creek along the drainage divide between the Bighorn Mountains and the Bridger range at elevations greater than 7,500 feet, that is, above the divide-summit elevations in the canyon area.

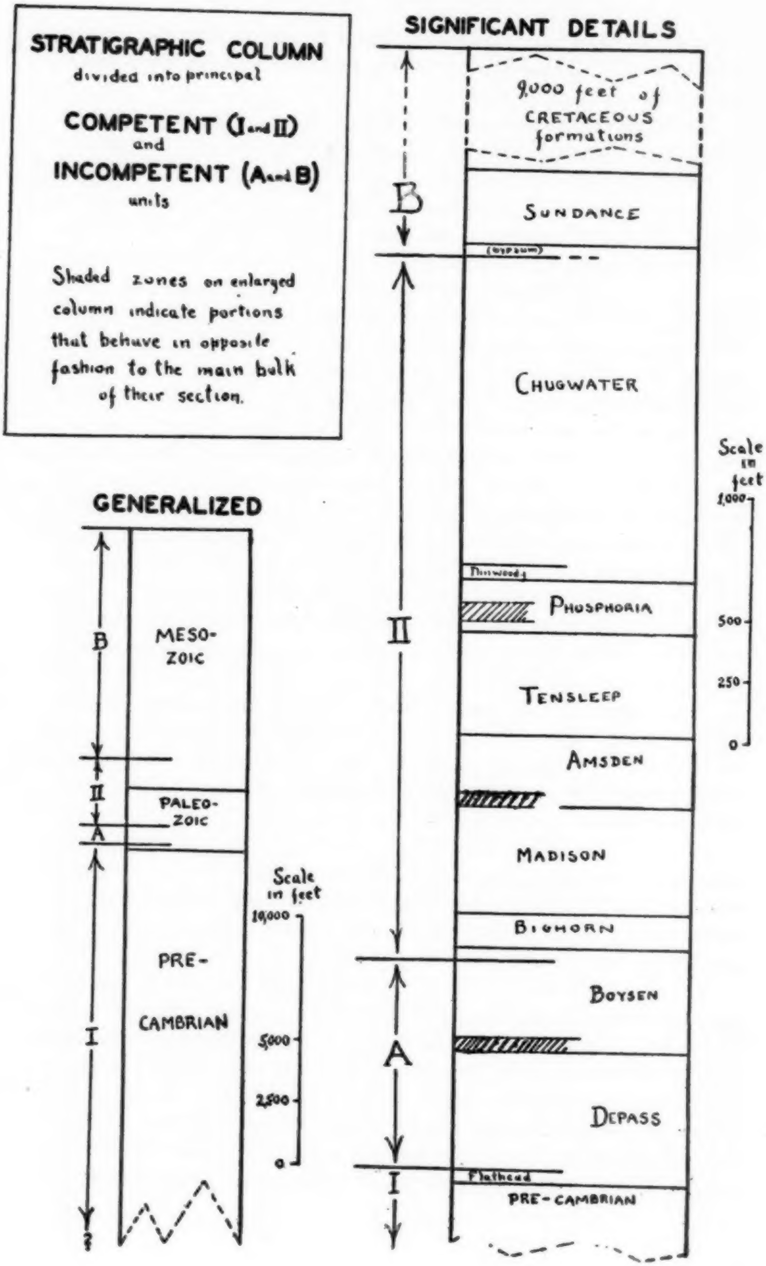
The sedimentary record is scanty after the deposition of the Wind River formation, and the geologic history must be interpreted in terms of land forms and erosion. Later sediments, found only against the lower flanks of the mountains, consist of terrace gravels (*Qgl* and *Qt*) up to 10 feet thick deposited on basinward-sloping erosion surfaces that bevel the underlying structures. Along the south front of the mountains, at least three terrace levels are discernible. Sloping north from the mountain front into the Bighorn Basin there was found only one terrace level; of the three investigated terrace remnants, the two nearest the Wind River Canyon are capped with travertine (*Qt*) as well as the ordinary gravels.

At greater elevations than the prominent terrace levels previously indicated, gravels are found here and there in the mountains. Though very few in any locality, they suggest the former existence of higher terrace levels that are now completely missing from the mountain borders and adjoining basins.

The age of the several terrace levels is not known; the veneer of fluvial gravels has yielded no fossils. They are the result of local stream rejuvenation and may be as late as Pleistocene in age. Mackin (28) considers the problems presented by similar terraces farther north within the Bighorn Basin. He illustrates clearly that separate terrace levels may not be considered to represent pauses in the uplifting of the region, as so many other factors (climatic change, stream capture, *et cetera*) may bring about the same result. Regional uplift

TABLE II

STRATIGRAPHIC COLUMN SHOWING COMPETENT AND INCOMPETENT UNITS, WIND RIVER CANYON AREA, WYOMING



is involved, but each terrace level does not constitute evidence for a time of stillstand between times of uplift.

Recent alluvium (*Qal*) along the present drainage channels completes the sedimentary record in the area.

Table I indicates the approximate thicknesses of the major stratigraphic units in the area; Table II expresses these thicknesses graphically and indicates the structurally competent and incompetent groups.

DETAILED STRATIGRAPHIC SECTION

(Measured in Wind River Canyon area)

The section from the Lakota (basal Cloverly) to the base of the Chugwater was measured on the south-facing escarpment 2 miles east of the highway bridge over the Bighorn River near the north end of the canyon.

LAKOTA conglomerate (*Kl*), Lower Cretaceous

Feet

16 Sandstone and conglomerate lenses capping escarpment; unconformable over Morrison

MORRISON formation (*Jm*), 305 feet thick, Upper Jurassic

150 Covered in part, mostly greenish sandy shales

25 Prominent cliff of light gray sandstone

95 Greenish sandy shales

35 Cliff of greenish sandstone, poorly consolidated. Notch occurs 20 feet from top due to a 1 foot bed of greenish shale

No obvious line of separation from underlying formation.

SUNDANCE formation (*Js*), 325 feet thick, Upper Jurassic

185 Partly covered, mostly greenish sandy shales. *Belemnites* occurs in upper portions; a few calcareous beds bear *Gryphaea* and fragments of other pelecypods

20 Brownish sandstone

40 Green shale, sandy in upper 8 feet

41 Chalk-white fine-grained jointed limestones; green, gray, and red shales; thin gypsum beds; and a "lithographic" limestone bed 4 feet thick beginning 5 feet from base

39 Crumbly red shale; unconformable over Chugwater. Thin gypsum stringers along and across bedding planes, may continue into underlying gypsum beds at top of Chugwater

CHUGWATER formation (*Trc*), 1,300 feet thick, Triassic (38)

50 Gypsum beds

1,250 "Redbeds." Red shales, sandy shales, and sandstones. Gypsiferous at top; a few thin beds of white, gray, green, or purplish shales; Lee's "Alcova limestone" (25) is 380 feet below base of gypsum. Two red sandstone members stand out as cliff-formers and divide formation roughly into thirds. Ripple marks common at many horizons

DINWOODY formation (mapped with Chugwater), 60 feet thick

TRIASSIC (38)

Best exposure on west side of river at north end of canyon. Light brown and yellow sandy shales capped by 15–20 feet of dark gray shaly and gypsiferous limestones. Basal contact covered

PHOSPHORIA formation (*Pp*), 205–235 feet thick, Permian (38)

White and gray limestones and gray shales. Smaller thickness is from section exposed on east rim of canyon, 3.5 miles in from north end; appended thicker section exposed in smaller canyon cut by Buffalo Creek 3 miles east of north end of Wind River Canyon.

60 Resistant member that forms "dipslope" on north flank of mountains. White and buff limestones, massive in middle 30 feet, thin-bedded above and below; scattered flecks of glauconite in lowest 10 feet

85 Thin-bedded light gray granular limestones; thin irregular chert bands in lowest 20 feet

40 Gray shale
25 White and gray limestones with irregular chert bands
25 Massive white limestones
Unconformable over Tensleep, but corresponds closely as to strike and dip. Basal 25 foot member is missing in 205 foot section; others vary somewhat

TENSLEEP formation (*Ct*), 380 feet thick, Lower Pennsylvanian (32). Section measured on east side of canyon, 3.5 miles in from north entrance
380 Massive and cross-bedded rusty brown sandstones. Forms high impressive "rim-rock" of canyon wall

AMSDEN formation (*Ca*), 260 feet thick, Chester epoch of Upper Mississippian (7, 32)
220 Buff and gray sandy shales and limestones of variable thickness (to 10 foot maximum) with interbedded irregular chert beds possibly as thick as 8 feet
40 Purplish shales; generally covered

MADISON formation (*Cm*), 450 feet thick, Mississippian
120 "Blue" member. Mainly massive gray limestone that weathers with faint but unmistakable blue, and forms rounded cliff projections in canyon. Fossiliferous in upper part, limestone breccia zone at base containing pink, yellow, and white fragments
330 Lower member, light gray limestones; thin, interrupted bands of chert at irregular intervals
130 Thickly bedded gray limestones
140 Platy, thinly bedded gray limestones, here and there geodes containing calcite crystals and shale "plasts" in upper 40 feet
60 Thickly bedded gray limestones. Basal contact difficult to determine; bedding planes parallel with underlying formation, disconformity

BIGHORN formation (*Ob*), 140 feet thick, Ordovician (Richmond stage, 30). Section measured in gully on east side of canyon, 6.5 miles by road from north entrance
140 Massive light gray dolomite containing scattered small quartz grains. Basal contact with underlying Cambrian gradational—sandy dolomitic phase 7 feet thick occurs at base. Weathered surfaces dark gray; formation is most prominent cliff-former in area

CAMBRIAN formations, 1,110 feet thick
Section measured near Smith's cabin, 9.7 miles by road from north edge of water hole at north end of canyon. In 1937, C. Deiss examined this section. His results (15) are agreed with and followed completely in this paper. Miller's "Depass formation" has been re-defined so as to include only those beds that contain a Middle Cambrian fauna, and the new term "Boysen formation" has been applied to the Upper Cambrian section.
In brief, the Cambrian section is made up of:
Upper Cambrian, *Boysen* formation 530 feet
Grove Creek member 40 feet
Snowy Range member 308 feet
Maurice member 182 feet
Middle Cambrian, *Depass* formation 580 feet
Gros Ventre member 300 feet
Flathead member 280 feet
A condensation of Deiss' measurements (15) follows.

BOYSEN formation (*Єb*), 530 feet thick, Upper Cambrian. Members are equivalent in age to formations of same names in Beartooth region of Montana.
Grove Creek member, 40 feet
40 Vari-colored beds of shale, limestone, and intraformational conglomerates. Graptolites found 14 feet from top, *Dikellocephalus* at base
Snowy Range member, 308 feet
90 Shales, limestones, and intraformational conglomerates. Maroon and green colors dominate in upper part, greens and grays in lower part
42 Covered
33 Shales, conglomerates, and limestones. Mostly dull green colors. *Ptychaspis* in lower tan limestone bed
124 Covered
19 Shales and limestones with interbedded intraformational conglomerates. Colors mostly greens and grays. Trilobites 4-6 feet from top

Maurice member, 182 feet

14 Green and gray limestones, with thin sandstone beds in upper part. *Aphelaspis* 8 feet from top

96 Prominent limestone cliff; mostly dull-and-tan-gray limestones and intraformational conglomerates. *Blontia*, *Kingstonia*, and *Tricrepicephalus* found 22 feet below top of cliffs; *Arapahoia* and *Blontia* occur 8 feet above base

62 Limestones, shales, and a few intraformational conglomerates. Colors mostly grays and greens. Trilobites occur 12 feet above base

DEPASS formation (*€d*), 580 feet thick (type section of B. M. Miller, amended by C. Deiss, 1937). Middle Cambrian

Gros Ventre member, 300 feet

100 Shales, limestones, and conglomerates; sandstones in lower 30 feet. Green and gray colors dominate. New genera of trilobites 10 feet from top

83 Shales and sandstones. Green, purple, maroon, and gray; worm tubes and glauconite at many horizons; *Glyphaspis* heads near top

117 Shales and sandstones. Green, maroon and gray; beds of glauconite and oölitic hematite in middle part; glauconite and worm tubes found at intervals throughout; *Glyphaspis* heads near top; trilobites in shale and sandstone near base

Flathead member, 280 feet

25 Gray and tan sandstones and greenish shales

124 Tan and gray sandstones and thinner beds of greenish shale. Corneous brachiopods and worm tubes at several horizons

124 Tan and gray sandstones and thinner beds of greenish shale; sandstones commonly cross-bedded. Worm tubes in some sandstones and shales, *Scolithes?* in lower part

7 Arkose, limonitic at base

Definite unconformity at base; no gradation of arkosic clastic sediments of Flathead member down through weathered material to fresh granite. However, pre-Cambrian weathering extends to maximum depth of 10 feet below basal Depass unconformity

Unconformity reveals pre-Cambrian relief of 30–45 feet; Flathead member varies in thickness accordingly

PRE-CAMBRIAN formations (19), (*p€*). No attempt is made to correlate them with other pre-Cambrian sections

Black and brown schists, intruded by pink and gray granites

All intrusives beveled by erosion surface that is now basal Cambrian unconformity

These pre-Cambrian formations are exposed for ½ mile on either side of Boysen Dam along the Boysen fault, and extend northward into the canyon as a diminishing wedge of outcrop. Between the canyon and Birdseye Pass on the east, a fork of Cottonwood Creek has cut back across the Boysen fault and exposed the black pre-Cambrian of the upthrown side of the fault. In the Birdseye Pass region the pre-Cambrian crops out also along the upthrown block of the Boysen fault, and spreads out as the main mass of Copper Mountain. The fault is lost in this area of pre-Cambrian rocks

In the canyon south of Boysen are two small outcrops exposed in upthrown sides of faults; both have been tunnelled by the C. B. & Q. Railroad construction

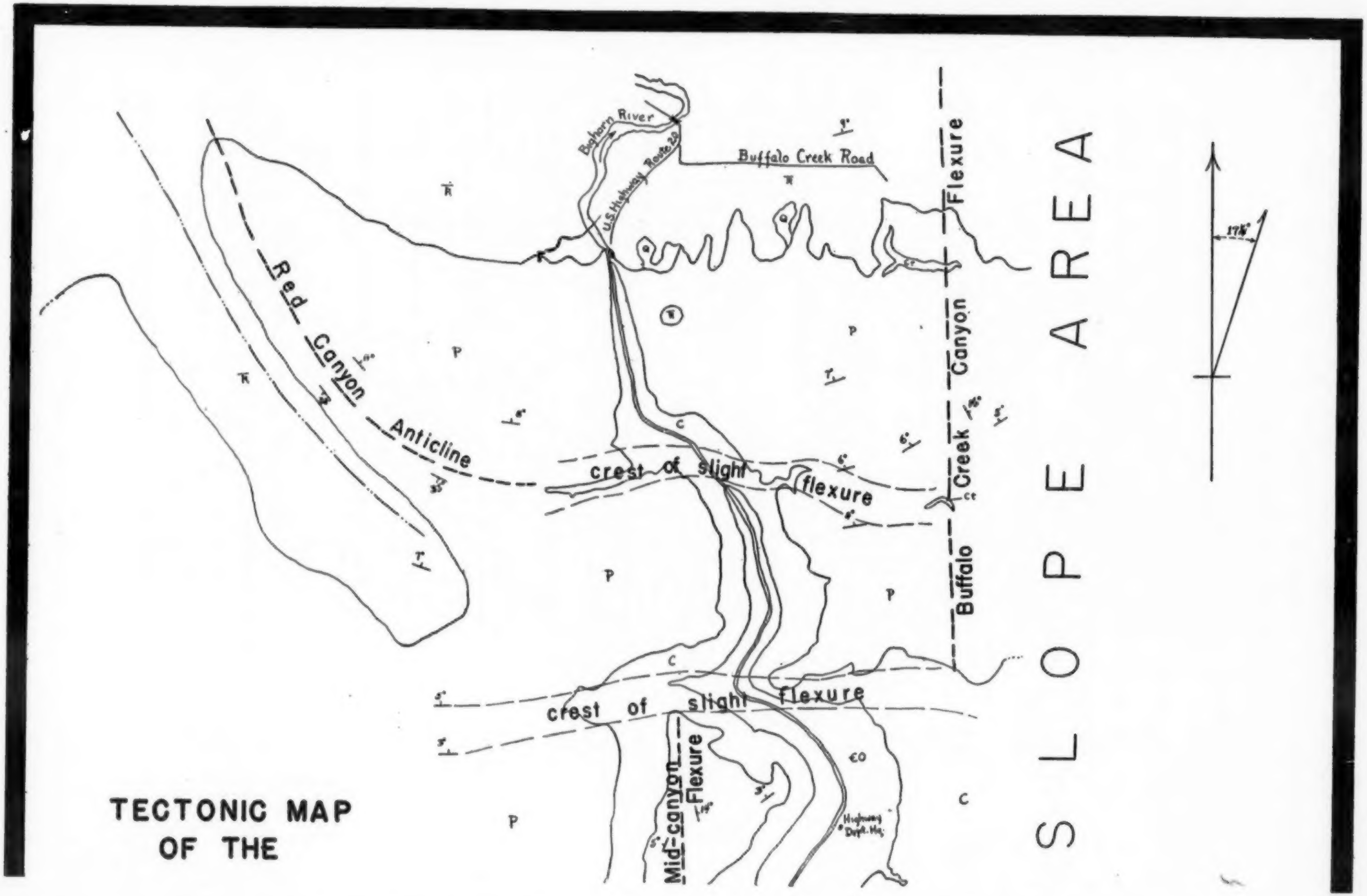
Much of the pre-Cambrian has been pitted with the barren prospect holes of gold-seekers

STRUCTURE

STRUCTURAL SUBDIVISIONS

The tectonic data presented in Figure 4 have been selected from the general geologic map of the Wind River Canyon area (Fig. 5) so as to emphasize and clarify the grouping of the structural features in this region of inter-basin deformation.

The pattern of the faults and flexures shown in Figure 4 suggests



TECTONIC MAP
OF THE
SLOPE AREA
Red Canyon Anticline
crest of slight flexure
crest of slight flexure
Buffalo Creek Canyon Flexure
Mid-canyon Flexure
Buffalo Creek Road
Bighorn River
U.S. Highway Route 20
Highway Dept. Hq.

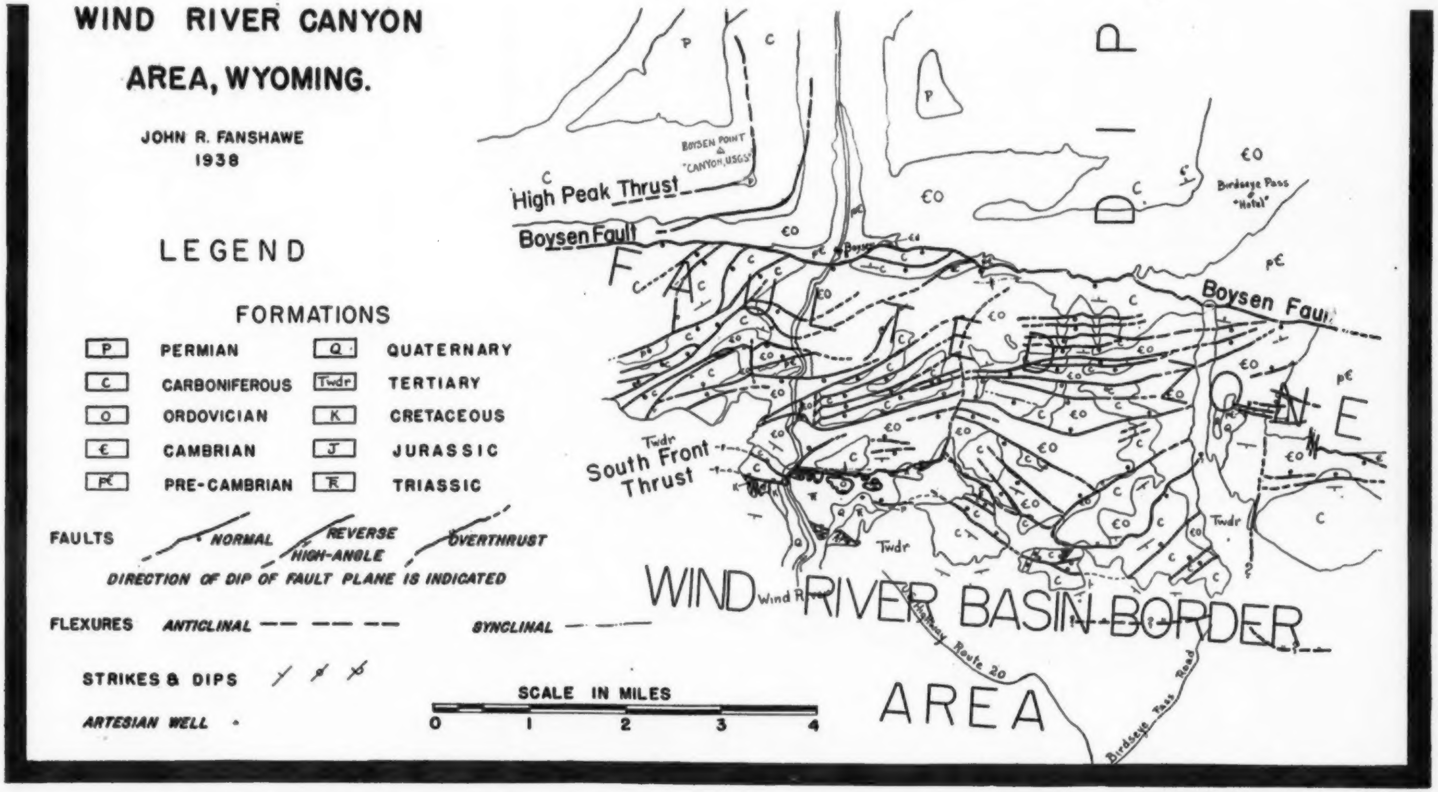
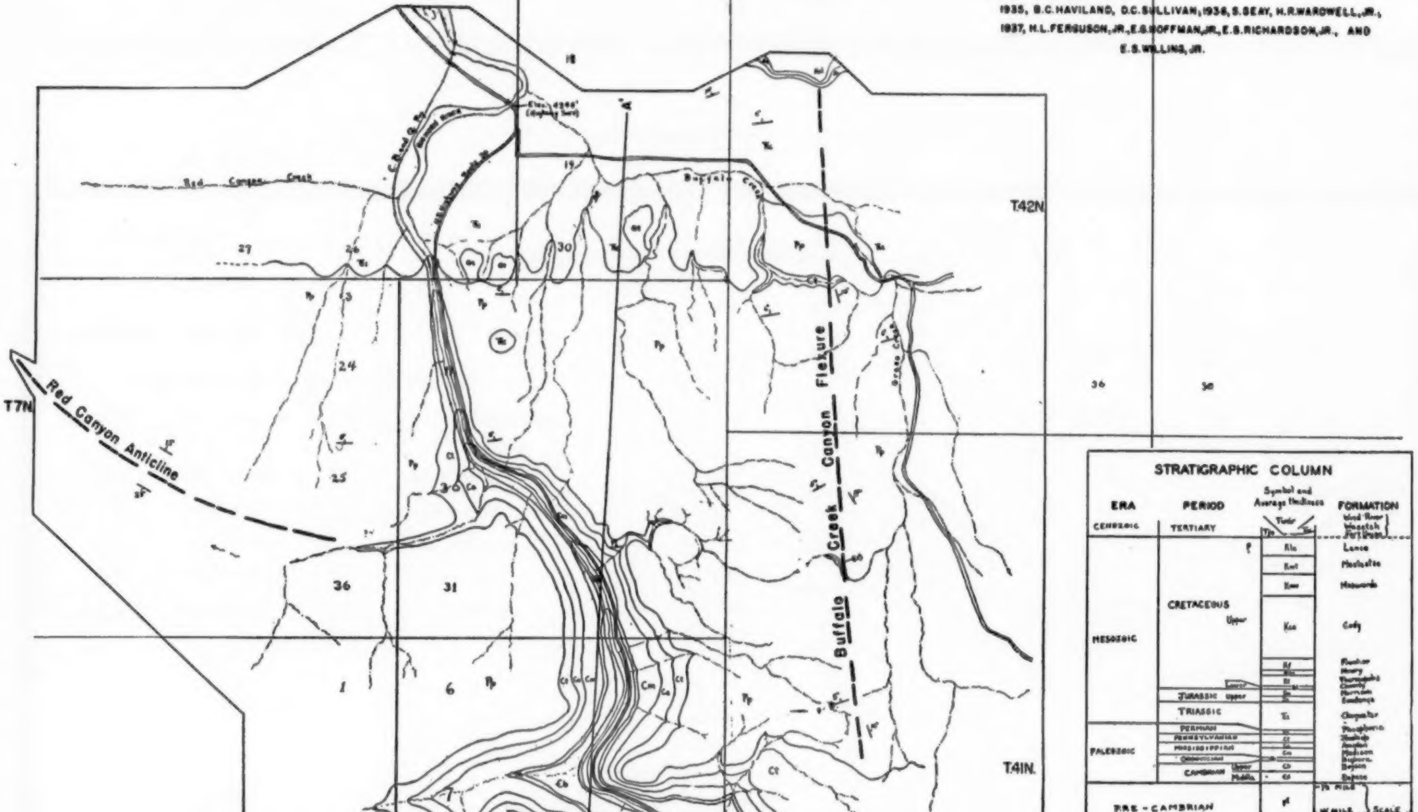


FIG. 4.—Tectonic map of Wind River Canyon area.

GEOLOGIC MAP OF THE WIND RIVER CANYON AREA, WYOMING.

JOHN R. FANSHAWE, 1938

FIELD ASSISTANTS:
1935, B.C. HAVILAND, D.C. SULLIVAN, 1936, S. SEAY, H.R. WARDWELL, JR.,
1937, H.L. FERGUSON, JR., E.G. HOFFMAN, JR., E.S. RICHARDSON, JR., AND
E.S. WILLINS, JR.



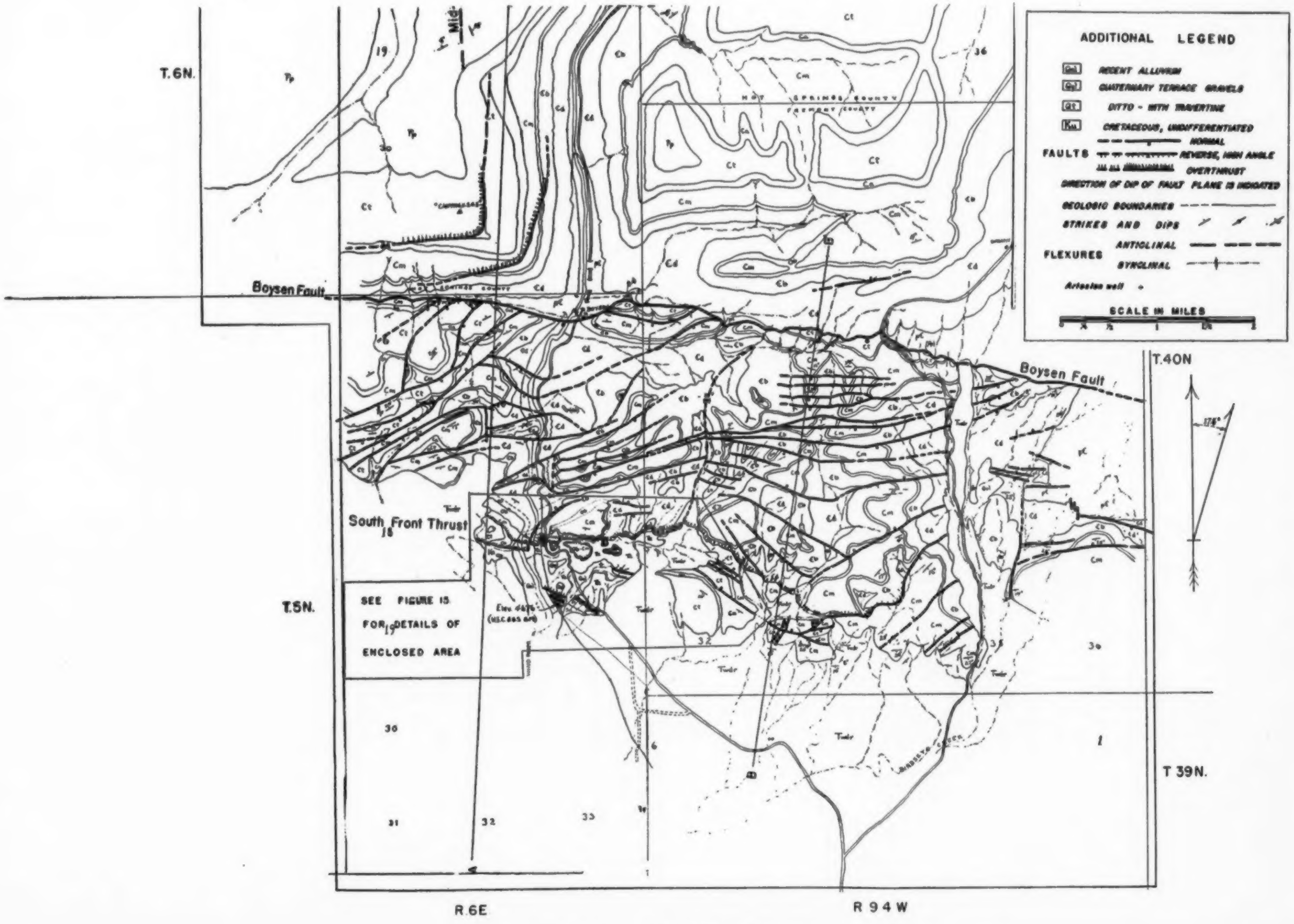


FIG. 5.—Geologic map of Wind River Canyon area.

a genetic grouping of these features on either side of the Boysen fault. North of that east-west fault the structural features present are typical of the Bighorn Basin region, and the Boysen fault scarp is to be regarded as forming the present southern rim of that basin. Directly south of this topographic basin rim lies a zone of complex faulting within which the dominant structural strike is east-west—with a northeast-southwest trend (not normal for the Central Rockies) also evident. Most of these fractures are secondary, high-angle normal faults of less than 500 feet displacement, but at the south entrance to the canyon major (primary) thrust faults are visible that bring Cambrian formations over those of Upper Cretaceous age.

Toward the south this whole zone of faulting passes beneath the Wind River formation of Eocene age which consists of coarse and fine clastic sediments that dip southward at angles of not more than 16°. These dips are wholly or mainly primary, and the formation overlaps across the beds deformed by the Laramide orogeny. This area of overlap is designated as the Wind River Basin border area in Figure 4, whereas those on the north are termed the faulted zone and the dip-slope area.

Thus there are three distinct genetic units in the area (Figs. 4 and 13) which may be defined as follows.

Unit 1. *Dip-slope area.*—This refers to the southern rim of the Bighorn Basin, and extends as far south as the Boysen fault.

Unit 2. *Faulted zone.*—This zone includes the fractured belt lying between the Boysen fault and the overlap of the Wind River formation. (It should be visualized as extending southward under the Wind River formation for a moderate distance.)

Unit 3. *Wind River Basin border area.*—This area is covered by the residual sediments deposited along the south flank of the newly built Laramide Mountains. These may have overlapped upon Unit 1 as well as upon Unit 2.

Unit 3 is described first in order to clear the way for the other two orogenically significant parts of the region. It is the "nuisance formation" in that it covers much of the desired tectonic data of the faulted zone.

UNIT 3: WIND RIVER BASIN BORDER AREA

The relationship of this area to the region investigated is shown in Figures 4, 5, and 13. In brief the basin border area is the uneroded sedimentary overlap of the Wind River formation that has buried the lower slopes of a pre-existent mountain range.

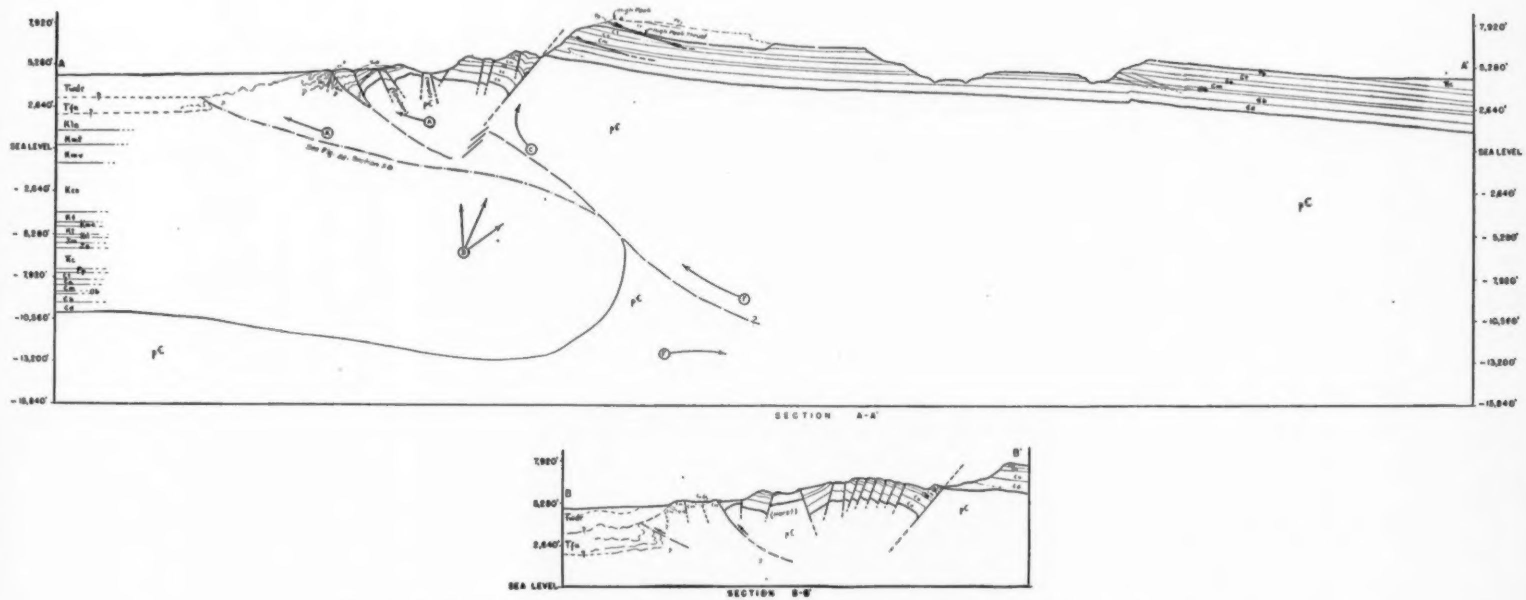


FIG. 6.—Sections interpreting structural geology in Wind River Canyon area. For location, see Figure 5.

The deformation of the Wind River formation is slight. None of the faults in the faulted zone or dip-slope area offsets the strata of this overlapping formation; consequently, the deformation of the mountain area was finished before the visible Wind River sediments were deposited.

Strike and dip measurements on Wind River strata (Figs. 4 and 5) show close parallelism to the attitude of the exhumed pre-Eocene mountain topographic surfaces, though dip readings for the Wind River strata are less steep, and vary between 8° and 16°. Thus the

FIG. 7.—Airplane view of north portal of Wind River Canyon. Upper limestones of Phosphoria formation underlie stripped dip-slope surface. Camera faces south.

Wind River deposits filled much of the basin at the south and buried and preserved the topographic contour of the lower levels of the Laramide mountain slopes. Present erosion is stripping the Eocene sediments from that topography along the edge of the Wind River Basin border area.

Slight anticlinal and synclinal warps in the Wind River strata exist a mile or more from the mountain front, but no strong folds, no thrust faults, and no normal faults with displacements greater than 5 feet have been found in the Wind River beds in this area.

UNIT I: DIP-SLOPE AREA

A broad impression of the relatively simple structural deformation in the dip-slope area may be gained from Figures 1, 7, and 8. As shown by these photographs, the surface is truly a dip-slope (developed on resistant upper Phosphoria limestones), and topographic irregularities are commonly the direct reflection of structural features.

FIG. 8.—View northward down Wind River Canyon. Continuity of structure across river is obvious.

In the immediate vicinity of the canyon the average direction of dip is a few degrees west of north. In the first 2 miles inside the canyon from the north the angle of dip may be as high as 9°; farther from the entrance, it is in few places more than 4°. This change in dip is indicated in Figure 4 as the northern crest of slight flexure. Two asym-

metric folds in the Phosphoria formation are found near the north entrance of the canyon; one, the prominent Red Canyon anticline (Fig. 4), meets the other, the monoclinal Buffalo Creek Canyon flexure at right angles through the aforementioned crest of slight flexure. The Buffalo Creek Canyon feature continues southward for 1½ miles across the area of diminished regional dips, and dies out against another, less obvious, east-west flexure. From this lesser arched zone a third asymmetric fold, the Mid-canyon flexure, ex-

Fig. 9.—Boysen fault at Boysen in Wind River Canyon. View looking eastward.

tends southward on the west side of the river—paralleling the Buffalo Creek Canyon flexure in all essential respects; assumably it is expressive of the northward (subsurface) continuation of the High Peak thrust, mentioned in the next paragraph.

Erosion has cut away the southern extension of the steeper limb of the Mid-canyon flexure. South of it is the highest peak in the area (Boysen Point, Fig. 1), which is underlain by the Tensleep sandstone. Between Boysen Point and Boysen Dam in the canyon below are found several low-angle thrust faults, the most significant of which are indicated on Figure 4. The High Peak thrust has placed basal Tensleep beds in mechanical contact with the lower limestones of the

Phosphoria formation; traced laterally, the fault plane disappears by distributive bedding-plane movement in the shales of the underlying Amsden formation. The northward subsurface continuation of this fault is apparently indicated by the Mid-canyon flexure in the superjacent Phosphoria beds.

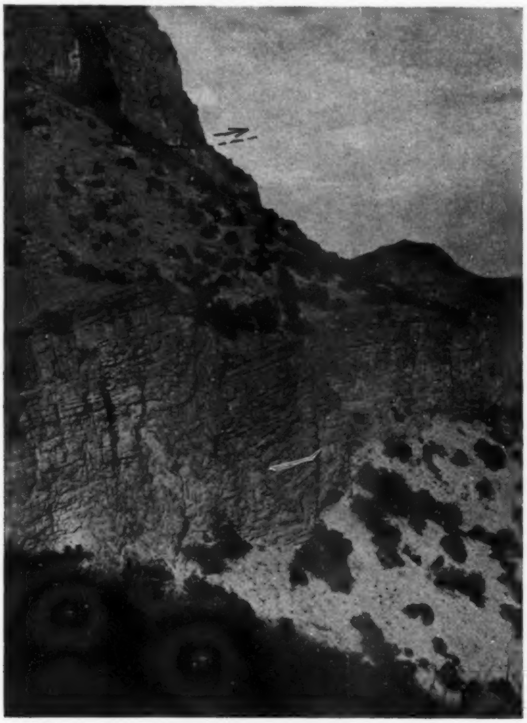


FIG. 10.—Structures typical of dip-slope area. Low-angle thrusts and asymmetrical anticlines in competent sedimentary formations. Camera faces east by north. (See Fig. 11.)

Similar thrusts of a few feet displacement are found in the competent formations on the north flanks of each of the slight flexure zones. In the thinner, though competent, limestone section of the Maurice member of the Boysen formation small asymmetric anticlines are also present within 3 miles of the Boysen fault. These features are too small to be shown on the maps. Figure 9 illustrates

one of these lesser anticlines beneath the lowest mapped thrust fault northwest of Boysen.

The Boysen fault marks the southern edge of the dip-slope area. It is shown from various directions in Figures 9, 11, 12, 13, 14, and 17.

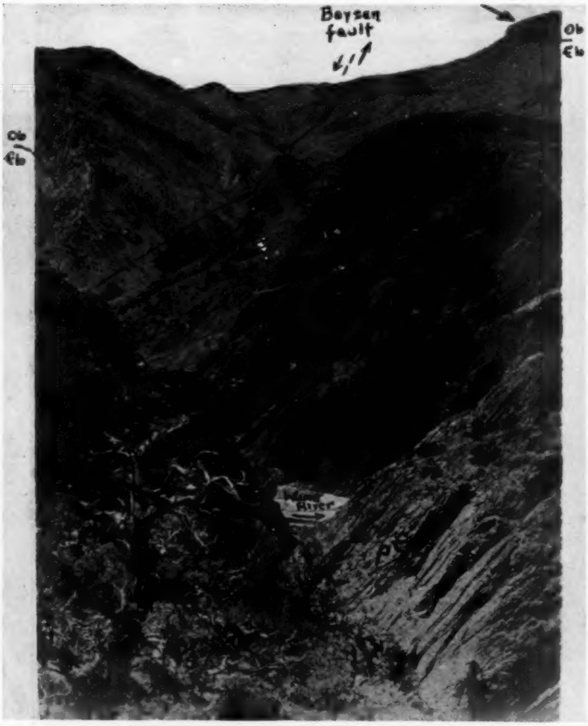


FIG. 11.—Boysen fault. Inner gorge of Wind River Canyon is cut through pre-Cambrian formations in upthrown block of fault. Arrow indicates same thrust fault shown in Figure 10. Camera faces west.

UNIT 2: FAULTED ZONE

General.—A general view of the nature and extent of the faulted zone section of the area may be had from Figures 13, 14, and 17. Figure 4 shows more clearly its east-west alignment; the Boysen fault (Figs. 12, 17, and 18) forms its northern boundary; and the Wind River formation overlaps its southern margin.

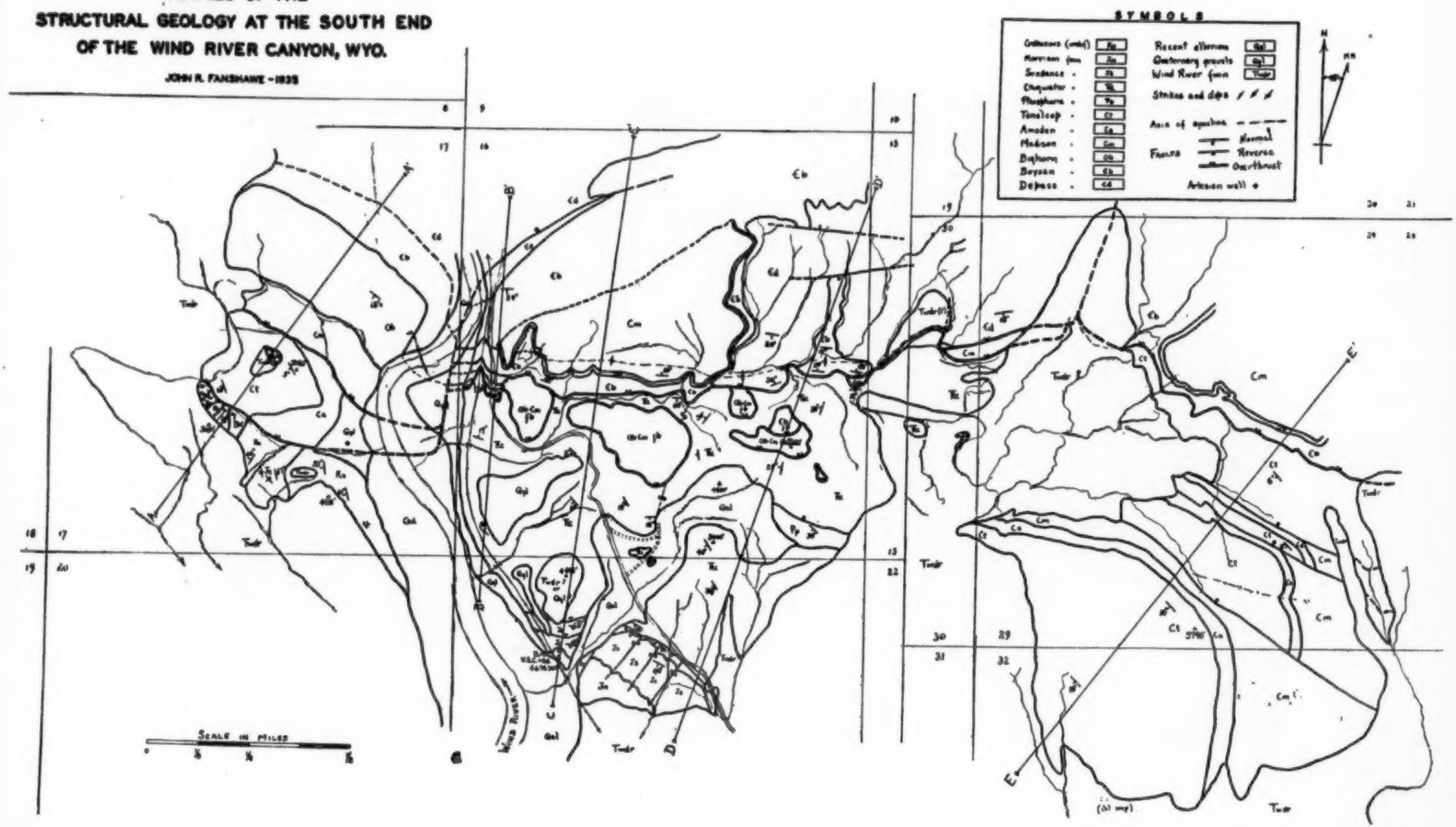
Southward overthrusting is found along the southern edge of this

FIG. 12.—Air view of Boysen fault and part of faulted zone. Camera faces east.

FIG. 13.—Air view of faulted zone. Solid line encloses part of region here shown that was mapped for this report. (See Figs. 4 and 5.) Camera faces east.

DETAILS OF THE STRUCTURAL GEOLOGY AT THE SOUTH END OF THE WIND RIVER CANYON, WYO.

JOHN R. FANSHAWE - 1939



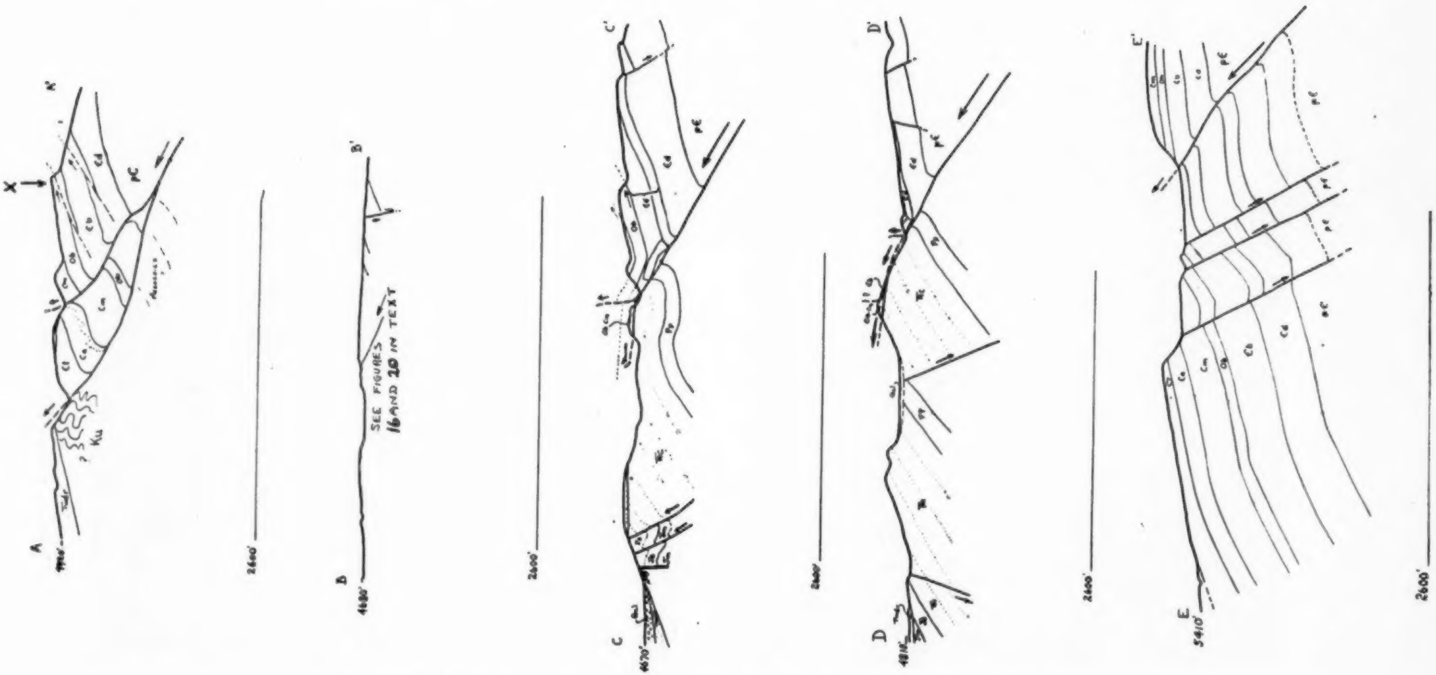


FIG. 15.—Details of structural geology at south end of Wind River Canyon, with cross sections.

FIG. 14.—Air view of faulted zone and Wind River at south end of Canyon. Boysen fault in left foreground; Wind River formation in right background; south front thrusts cross river where Highway 15 swings east. (See Fig. 18.) Camera faces south by east.

FIG. 16.—Thrust fault in railroad cut at south end of Wind River Canyon. Compare with Figure 19, a closer view of same fault plane. Camera faces southeast.

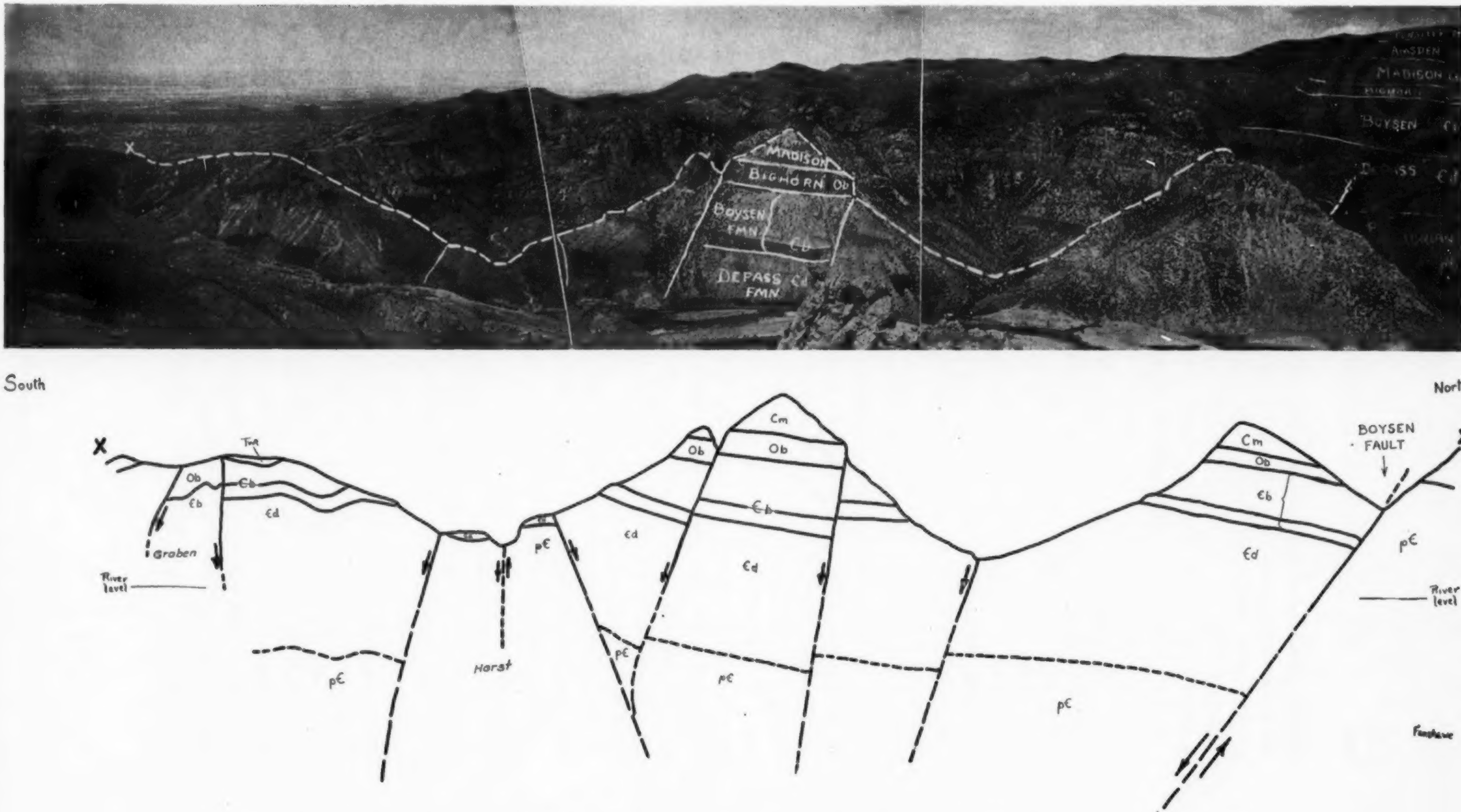


FIG. 17.—Structure visible along west side of canyon, southward from Boysen fault. White dashed line indicates surface for profile drawn below panorama. X at left end of line is reference point repeated on Figure 18.

faulted zone area of outcrop. Here klippen and fault traces show Cambrian formations overthrust upon Jurassic and older strata, and adjacent Cretaceous (and Paleocene?) sediments have been intensely deformed (Figs. 15, 16, 18, 19, 20, and 21). The main part of the zone is crossed by a great number of east-west and northeast-southwest high-angle faults with stratigraphic displacements of less than 500 feet. Tear faults extend back northward and northeastward from the south front thrusts (Figs. 4, 5, and 6) and divide the zone into more or less distinct sections. Northward back-thrusting, with less than 200 feet of movement along the fault planes, is present just north of the south front thrusts.

Section AA' (Fig. 6) is reconstructed from evidence obtained from the west side of the Wind River Canyon. Photographs (Figs. 17 and 18) were taken to aid in visualizing the structural conditions shown in this section, and Figures 9, 11, and 12 also show that the Boysen fault has a 40° hade and brings pre-Cambrian rocks into contact with the Pennsylvanian Tensleep formation. It is a normal fault—notable, however, for the fact that the relatively downthrown Depass, Boysen, Bighorn, and Madison formations curve *down* into the fault plane; that is, the drag they manifest is in a direction opposite to that ordinarily exhibited by a downdropped block. Examining Figure 17 from north to south, one sees tilted blocks bounded by normal faults of small displacement; a horst; then a north-tilted graben (the angle and perspective of the photograph makes it appear vertical; see also section AA' on Fig. 6), followed by strata that dip away from the camera.

An X is marked on the Bighorn cliff at the end of the line of section, and that point is indicated on Figure 18.

Figure 19 (and section AA' in Fig. 15) shows the south-dipping Cambrian (*€d* and *€b*) and Ordovician (*Ob*) strata (the Bighorn cut by a small reverse thrust) and the brecciated Madison limestone (*Cm*) in mechanical contact with Amsden and Tensleep rocks that also dip southward. Near the edge of the picture, the Tensleep is in turn overthrust upon intensely deformed Jurassic (?) and Cretaceous sediments (see also right foreground of Fig. 21). The continuation of the faulted zone is obscured from this point southward by the overlap of the undisturbed Wind River formation.

Section AA', just described, contains the typical elements to be seen in any north-south section across the faulted zone. Section BB' (Fig. 6) may appear to refute this statement unless it is realized that many of the faults are not continuous for more than 2½ miles, and that most faults in this zone die out or meet another fault within that

distance. The horst feature is commonly present between the south front thrusts and the Boysen fault, making apparent the lift of the medial part of the faulted zone relative to the margins. Most faults north of the horsts are subparallel to the Boysen fault in strike, dip, and direction of movement; south of the horsts there may be minor high- and low-angle reverse faults, normal faults, and major overthrusts.

Thus, from north to south in the vertical plane, there are certain ever-present features: the Boysen fault; sympathetic little-Boysen faults; a medial elevated area, commonly consisting of a horst with a steeper fault bounding it on the south; and a heterogeneous zone in which are found the south front thrusts.

Boysen fault.—The Boysen fault itself (Figs. 9, 11, and 12) is the most strikingly visible single feature in the area. It trends nearly east-west (N. 80° W. in the canyon) for more than 10 miles (Figs. 2, 4, and 5), hades 40° to the (relatively) downthrown block on the south, and has a maximum observed stratigraphic displacement of 2,500 feet 3 miles east of Boysen (the pre-Cambrian there being against the Phosphoria formation). The Boysen fault dies out gradually at its west end, and is lost in the pre-Cambrian exposures of Copper Mountain at its eastern end—though it continues to be traceable for some distance farther on airplane photographs. The throw of the fault may be greatest east of the point of observed maximum displacement; unfortunately, as erosion has removed the Cambrian and later strata from the lifted block on the north, and all but the Cambrian formations from the dropped block, reference data for determining throw cease to be available. Where erosion has cut deeply along the fault plane (Figs. 5 and 6) it can be seen that the strata of the relatively downthrown block dip *into* the fault plane instead of away from it. Lesser faults of the faulted zone (many of which terminate against the Boysen fault) characteristically swing from a northeast-southwest strike to an east-west trend where followed away from the Boysen fault.

Major thrusts.—Along the southern exposed margin of the faulted zone is the great south front thrust fault, or group of overthrusts (Figs. 18, 19, 20, and 21). The stratigraphic displacement of these thrusts is at a maximum near the canyon and decreases as they are followed eastward from the *AA′* sections (Figs. 6 and 15). West of the river the lower exposed thrust plane passes above Upper Cretaceous sediments, whereas east of the river the thrusts cut across the tilted Triassic. In the railroad cut (Figs. 16 and 19) the soft gypsum member of the Chugwater formation lies directly beneath the thrust plane.

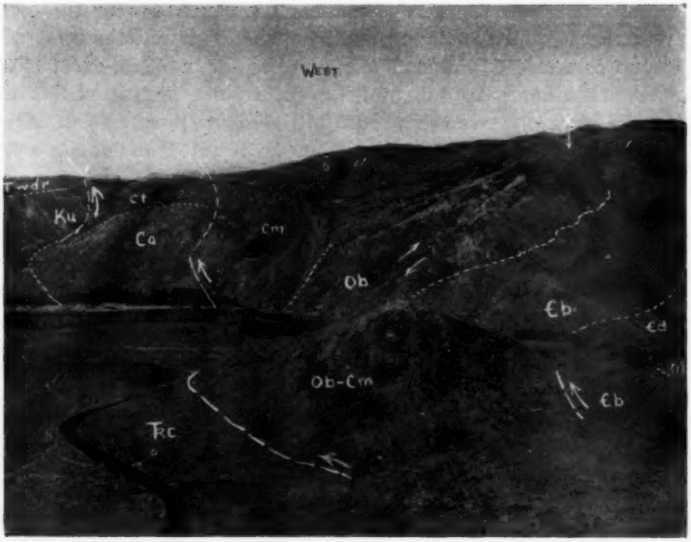


Fig. 18.—South front thrusts, associated structures, and overlap of Wind River formation at south entrance of Wind River Canyon.

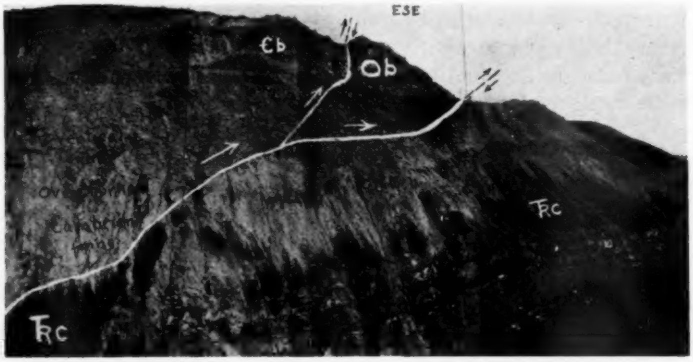


Fig. 19.—Details along thrust plane in railroad cut at south entrance of canyon. Compare Figure 16. This railroad cut is shown in Figure 20 at the extreme left of picture.

Still farther east, in section *EE′* (Fig. 15) the Boysen formation is in contact with the Tensleep; in section *BB′* (Fig. 6) the stratigraphic throw has diminished, so that Boysen is against Madison. The thrust

then swings northeast as a high-angle fracture, even though typical faulted zone structure persists into the Birdseye Pass valley area. At the point where the Birdseye Creek road enters the mountains on the south (Fig. 5), the Madison formation is brecciated—suggesting the probability of another major thrust fault at slight depth below the surface.

The thrust movement along the south front fault is intricate. In the railroad cut at the south end of the canyon (Figs. 16 and 19) it can be seen that each of the more competent members of the Cambrian section has been shoved against the one normally above it, involving much minor folding and thrusting, and this Cambrian complex has in turn been thrust against larger and more resistant blocks of the Bighorn-Madison competent unit. This imbricated material is at the base of the observed overthrust mass (Figs. 20 and 21).

The south front thrusts are interrupted by tear faults. The nature of the tears is best seen at the south end of the canyon (mapped in detail in Fig. 13) which is one of the few places where the strata on either side of the river do not match. In the railroad cut east of the river, and in the hills east of the highway (Figs. 19 and 20) a deeper part of the thrust plane is exposed than is visible on the west river bank (Fig. 15). This is due to a tear, or split, in the overthrust mass as the eastern part rode higher than the western as both moved south. This tear, or split, swings around toward the northeast and becomes a normal fault, hading to the downthrown block on the outside of the arc (toward the northwest). This set of relationships is repeated at least twice as the trace of the thrust is followed eastward (Figs. 4, 5, 6, and 15).

The presence of a pre-Cambrian exposure extending south of the east end of the Boysen fault is probably due to the presence of a tear fault of similar character, but so much is covered by the overlap of the Wind River formation in this locality that proof is not available. Reconnaissance east of the mapped area shows that north-south faults ordinarily have the east side of the fracture either lifted or moved farther south than the west side.

Lower thrusts.—The region south of and beneath the south front thrusts offers poor exposures; however, from it may be gained some evidence that more thrust faults are covered by the Wind River formation. In particular, the area near the U. S. Coast and Geodetic Survey elevation Bench Mark is significant (Fig. 5 and section *CC′* in Fig. 15), as southward thrusting, and overturning of the Jurassic section, have taken place, with the Chugwater composing the upthrown block. The check of further observations is prevented by the blanket of Wind River sediments.

Relationships not present.—Finally, it may be pointed out that certain relationships do not exist within the observed limits of the faulted zone. The general east-west structural alignment is interrupted by faults trending northeast-southwest and faults or shear zones trending north-south, but there is no indication that any fault has offset a previous set of faults; instead, similar kinds of faults are found in each north-south sector. Normal faulting of the thrust planes might be expected (and may be present) but has not been recognized;

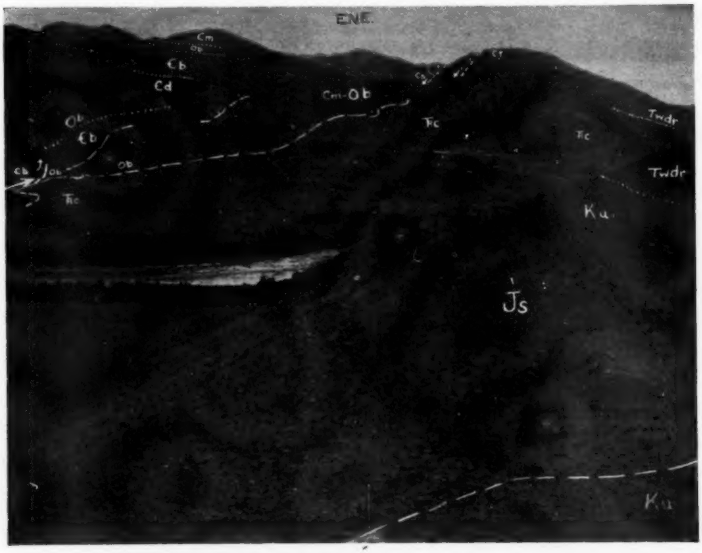


FIG. 20.—Mountain front at south end of Wind River Canyon. Trace of thrust planes is indicated by dashed lines; dotted lines show formational boundaries. Sections *CC′*, *DD′*, and *EE′* (Fig. 15) cross background area.

instead, there is minor back-thrusting in the overriding block. Thrust faults, usually attributed to compressional forces, and high-angle faults that are ordinarily attributed to crustal tension, occur together in the faulted zone—definitely suggesting that they have been respectively primary and secondary products of the operation of one set of deforming forces.

DATING OF OROGENIC MOVEMENTS

In the western part of the mountains flanking the Wind River Basin on the north, Love (27) has found indication of three main

episodes of crustal shortening: (1) in post-Montana-pre-Paleocene time; (2) during post-Paleocene time; and (3) near the close of the late Lower Eocene. He finds localized deformation of lesser magnitude during the close of the Middle Eocene, during the close of the Upper Eocene, and in post-Oligocene time—which last phase he states may possibly be associated with the intrusion of igneous rocks.

Hewett (22, p. 68) has shown that folding preceded the deposition

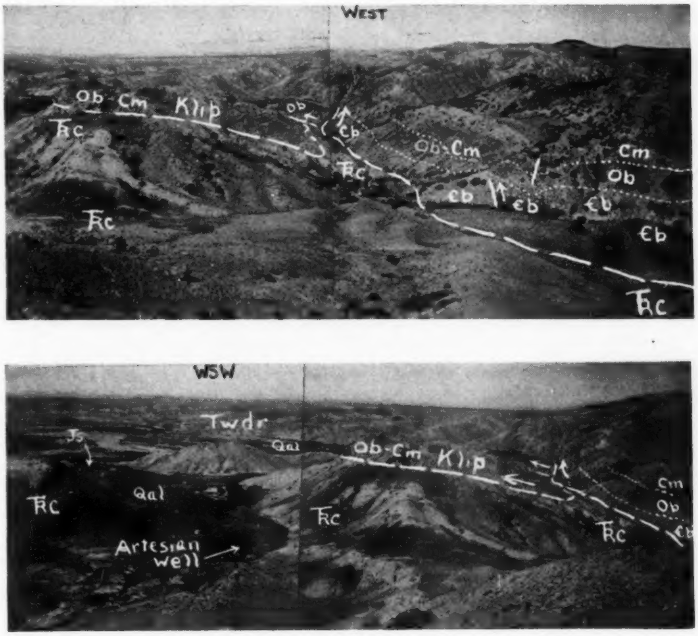


FIG. 21.—Two views of same klippe, to illustrate details of structural deformation along southern exposed margin of faulted zone. Wind River in middle distance. Section *CC'* (Fig. 15) is drawn across klippe here illustrated. Position of artesian well will serve to orient reader.

of the basal Fort Union beds in the southwestern border area of the Bighorn Basin; that strong folding of post-Fort Union-pre-Wasatch age occurred; and that localized folding of slightly later date may have occurred there.

Dating evidence as yet available in the Wind River Canyon area is meager. Along the south front of the mountains where southward

overthrusting took place, the youngest exposed formations involved in the Laramide compression include strata of Upper Cretaceous age. The almost undisturbed Wind River formation of Eocene age irregularly overlaps the truncated edges of the earlier deformed sediments. Latest Cretaceous and Fort Union formations have not been recognized in the small outcrop areas where they might be expected to occur. The blanketing Wind River formation along the mountain front is a coarse facies (not a basal conglomerate) that belongs somewhere in Wind River time. There is, at least, indication that the Laramide stresses had ceased to operate during Wind River time, as the dips in the exposed Wind River formation reflect the slopes of the underlying mountain topography and none of the faults of the mountain complex has been observed to affect the Wind River formation. In terms of local evidence, therefore, it is not possible to bracket definitely the time of orogenic disturbance any closer than pre-late Wind River and post-mid-Upper Cretaceous.

The work of C. Max Bauer in the Wind River Basin (3) may be referred to for evidence on the timing of Laramide movements while the deformation of the mountains was progressing. Bauer states in this connection: "Wherever observed in this area, the Fort Union formation has been deformed with the underlying Cretaceous. The Wind River formation is less intensely folded . . ." The post-Fort Union folding is considered the result of Laramide compression, and the post-Wind River folding is attributed to a renewal of the orogenic movements.

From the foregoing evidence, the major time of compression in the Wind River Canyon area is correlated by the writer with the unconformity above the Fort Union formation. As mentioned later, the writer also believes that the dips in the Wind River formation along the north edge of the basin reflect the slopes of the buried mountain topography, and suggest compaction and regional warping as their direct cause—rather than a renewal of the Laramide compressive stresses.

Provisionally, then, the orogenic movements in the Wind River Canyon area are considered as occurring chiefly at the close of Fort Union time, with minor movements recurring before or during the earlier part of Wind River time. The structures developed in the Wind River Canyon area belong to a phase (or phases) of crustal compression that could not have continued later than the beginning of deposition of those Wind River sediments that now visibly overlap the south front of the Owl Creek-Bridger Mountains.

NATURE AND DIRECTION OF LARAMIDE DEFORMATIONAL MOVEMENTS

Inter-basin movements.—Orogenic deformation does not affect the visible sediments of the Wind River formation; thus, Laramide deformational features are to be found only north of (or beneath) the Wind River overlap in the Wind River Basin border area (Fig. 4).

Appreciation of the magnitude of the vertical differential movement in the region may be gained by using the basal Cambrian unconformity as a reference plane. The top of the pre-Cambrian is exposed in the upthrown block of the Boysen fault in the canyon at an elevation of approximately 5,300 feet above sea-level (Figs. 9 and 11). At the south there are two pre-Cambrian outcrops (Figs. 4 and 5), the surfaces of which are slightly less than 4,750 feet above sea-level. At the south end of the canyon, less than a mile from the nearest pre-Cambrian exposure, folded Upper Cretaceous formations are found (Figs. 15, 18, and 20). The axis of the Wind River Basin lies close to its northern margin, and a short distance south of the mountains, and within this trough there is estimated to be 15,000 feet of section below the Wind River formation, and above the basal Cambrian unconformity (Tables I and II, and Fig. 5). Thus a vertical differential of approximately 16,000 feet has been brought about in consequence of, and in intimate association with, the overthrusting.

Considering the geometry of the observed surface structures, and the 16,000 feet of vertical differential postulated, the horizontal component of the southward movement for the overthrust block is estimated at about 6 miles. Section *AA′* (Fig. 6) is a north-south structural section extending across the entire length of the area, to illustrate the nature of this deformation.

For the overthrust materials, the chief direction of movement in the horizontal plane is clearly southward. That the movement was of greater extent than can now be measured is indicated by the eroded front of the klippen south of the main fault trace east of the river (Figs. 15 and 21).

Southward thrusting along planes of movement beneath and south of the exposed southern margins of the faulted zone must also be postulated. For example, the south end of section *CC′* (Fig. 15) shows minor thrusting a half mile south of the better exposed south front thrusts. A comparison of sections *AA′* and *BB′* across the faulted zone in Figure 5 shows that the south front thrusts of section *AA′* are represented by a single, higher, thrust plane of less displacement in section *BB′*, whereas the Madison outcrops south of the thrust on section *BB′* indicate an essential continuation of the total amount of vertical differential movement—which can be accounted for in

cross section only by assumption of a second major, northward-dipping, thrust plane *beneath* this outcrop. Brecciation of the Madison limestones at the south entrance to the Birdseye Creek valley, and the southern extension of pre-Cambrian outcrop on the east side of this valley, constitute contributory evidence that the *entire* faulted zone is underlain by one or more major, north-dipping, thrust faults.

Across any north-south sector of the faulted zone a medial lift relative to the margins is evident. The casual impression is received that the zone is a faulted anticline—actually there is little or no folding present. The high-angle normal faults bound blocks of tilted strata and are ordinarily the continuous expression of fracture planes in the subjacent crystallines (best illustrated in Fig. 17).

The minor reverse faults in the faulted zone are direct or secondary consequences of the major overthrusting, and throw in opposite direction. Figure 18 shows one such minor thrust in the Bighorn formation that may be attributed to back-bulging of the overridden strata. These minor thrust faults are due to such bulging of the overridden sediments beneath the thrust sole, and thus occur only as far north of the present major overthrust traces as the southern margin of the crystallines in the overthrust plate permits.

The Boysen fault is a key item in the interpretation of the orogenic sequence of events. It is a big feature (Figs. 9, 11, and 12), nearly straight for more than 10 miles, and constitutes a definite boundary between areas that are structurally dissimilar. As previously stated, the fault hades to the downthrown block on the south, yet the observed drag phenomena in the strata of the downthrown block indicate a reversed movement. Faults adjacent to it on the south strike either parallel with it or approach a northeast-southwest trend, and the downdropped block of each fault plane is on its southern side. The outcrop pattern of these faults suggests a tendency for the upthrown block of the Boysen fault to have moved eastward as well as relatively upward.

Renewal of effective north-south compression after the Boysen fault had been formed apparently must be appealed to to account for the reversed-drag phenomena noted (Fig. 22).

The Boysen fault, then, is interpreted as a moderate-angle fault (dip of 50°) that developed late in the orogenic growth of the region. It was brought about after compressional forces were largely dissipated by overthrust movements. The upward bulge of the stump of the pre-thrust Bridger-Owl Creek anticline continued to lift the rear part of the overthrusting mass, eventually resulting in the upfaulting of this rear part, relative to the broken-up toe of the overthrust—

which now lies south of the Boysen fault. The upthrown block of the Boysen fault would thus be taken to mark the southernmost part of the overthrust material that was elevated by further growth of the original anticline, whereas the area south of the Boysen fault, designated as the faulted zone in Figure 4, is the broken-off toe of the overthrust, which had pushed southward beyond the axis of the original anticline, and hence was not lifted by the further lift of this fold as it was further compressed after rupture.

As already stated, there was renewed or continued crustal compression during and after the formation of the Boysen fault. The amount of such movement is open to question, and the mechanics involved can be stated in terms of at least three alternative possibilities (Fig. 22, stages 4, 5A, and 5B). In any case this final phase was definitely a minor one.

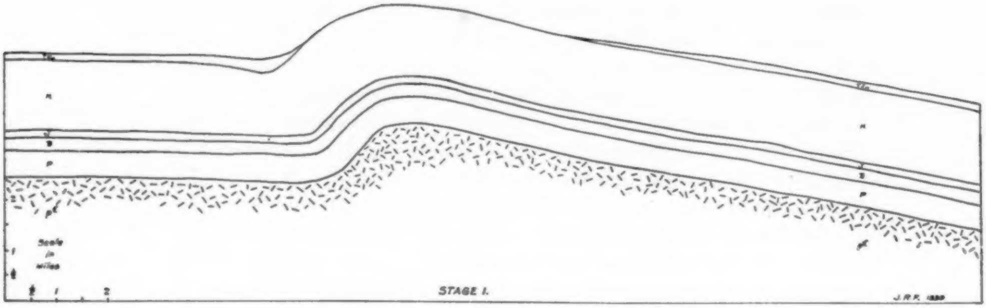
1. The first of these (see Fig. 22, stage 4) is that the final compression was effective only to the extent that it caused an apparent reverse drag along the Boysen fault, and adjustment at depth was made possible by the flowage of the incompetent sediments beneath the interrupted thrust plane or planes.

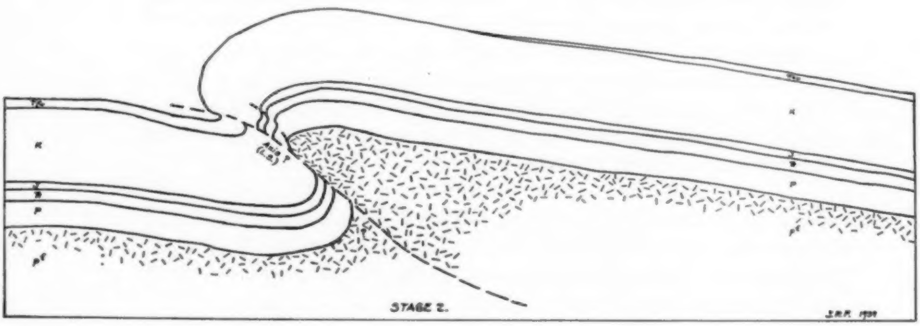
2. The second mechanical interpretation which can be offered (Fig. 22, stage 5A) is that the unexposed basal northward-dipping thrust plane was offset by the Boysen fault; renewed crustal shortening took place as a new upper continuation of the interrupted fault plane developed across the downdropped toe of the thrust mass, resulting in the south front thrusts.

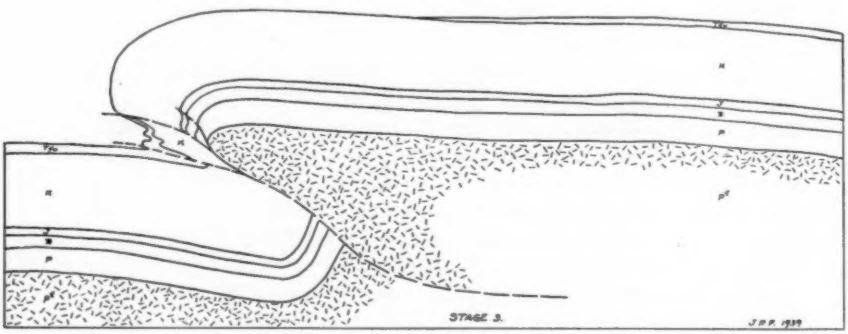
3. The third explanation (Fig. 22, stage 5B) is that the south front thrusts (or possibly deeper planes of movement) were the surface expressions of the main plane of overthrusting which was offset by the Boysen fault. Due to the highly competent nature of the pre-Cambrian rocks underlying most of this part of the faulted zone, the renewed compression was transmitted by this unit and a lower ("sole") thrust plane developed across the distorted underlying incompetent formations, allowing the previously formed faults that are now visible in the broken-off toe of the thrust mass to ride forward relatively unmodified. This interpretation was accepted by the writer in the construction of section *AA'* (Fig. 6).

Regardless of the postulate, the entire faulted zone, plus part of the southern margin of the dip-slope area, has been overthrust southward.

Intra-basin movements.—The flexures and faults observed in the dip-slope area (Fig. 4) belong genetically within the Bighorn Basin and are the products of basin mechanics. They are related to the


STAGE I.


STAGE 2.


STAGE 3.

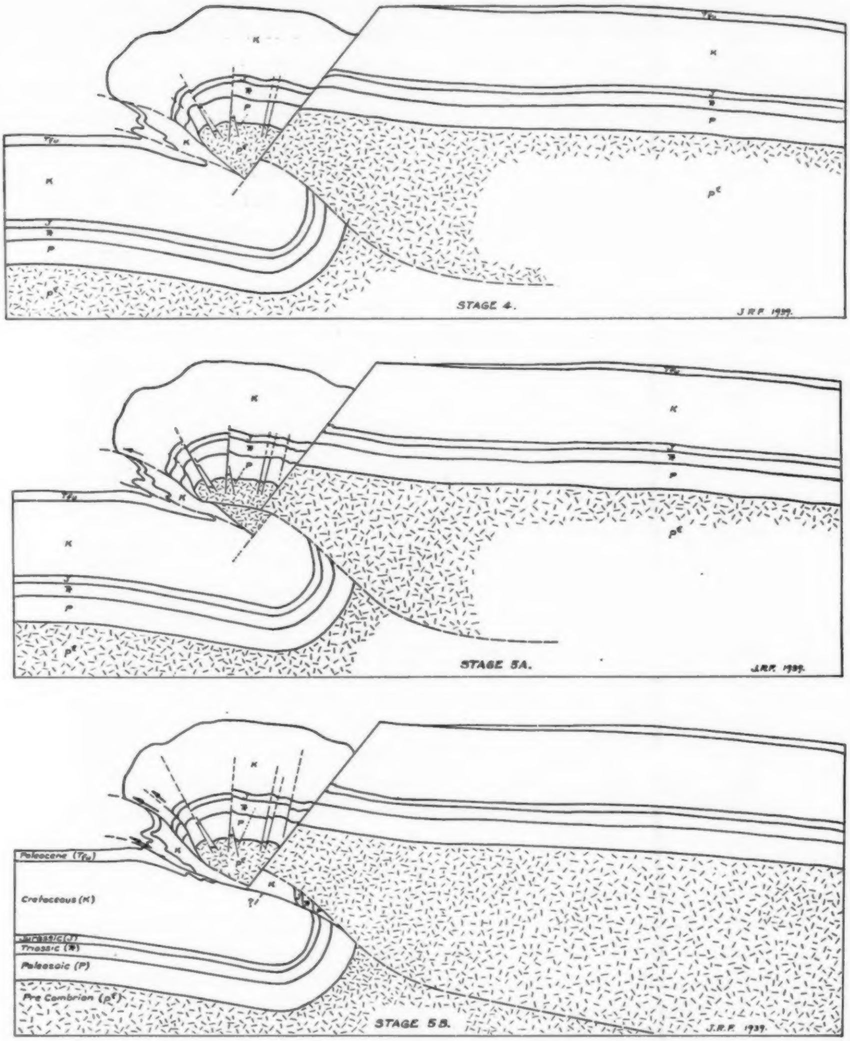


FIG. 22.—Stages in structural development of Wind River Canyon area. Contemporaneous erosion and accompanying basin-mechanics developments are omitted.

Section 1 shows late Cretaceous asymmetry and probable position of Fort Union formation of Paleocene age.

Sections 2 to 5A (or 5B) indicate tectonic stages involved in structural growth of region as a result of Laramide compressive forces. Time represented is post-Fort Union to pre-late Wind River.

Postulates 1, 2, and 3 on page 1481 are illustrated by sections 4, 5A, and 5B, respectively. Sequence is drawn to lead directly to conditions shown in section 5A. From section 4, postulate 1 may be arrived at by effective compression along Boysen fault that is taken up by distributive movements in underlying overridden material.

faulted zone structures only in so far as the latter served to increase the differential depression of the central part of the Bighorn Basin relative to its southern margin.

"Basin mechanics" is an expression coined by Thom (35, p. 110) to apply to the formation of near-surface thrusts and superjacent asymmetric folds in consequence of the flexing into basin form of massive, competent, rock units either devoid of bedding planes, or lacking enough bedding to permit easy and well distributed bedding-gliding of successively higher layers toward the rims as a basin depression developed in consequence of general regional compression.

The nature and distribution of the ramp-like features produced by such flexing of the unbedded basement rocks into basin form has been described in the Guidebook of the Bighorn Basin-Yellowstone Valley Structural Field Conference of 1937 (see also Fig. 2), and some of the typical asymmetric anticlines ringing the Bighorn Basin are surface reflections of such ramp-like thrusts in the basement rocks beneath. The exposures in the Wind River Canyon also suffice to show that the relatively unbedded and competent limestone units in the local Paleozoic section (see Table II) also lack sufficient facility for distributive bedding-plane gliding when flexed and consequently develop outwardly directed low-angle thrust faults and asymmetric anticlines with overthrusting or overturning away from the basin (Fig. 6, *AA'*, and Fig. 10)—whereas the thinner-bedded shales develop differential gliding on bedding planes. The faults and folds of the limestones consequently die out above and below the competent unit by distributed movements in the shales, and are reflected upward mainly by passive draping of the less competent and more thinly bedded superjacent formations.

Observed thrust faults in the dip-slope area are consequently restricted to the thick competent members of the stratigraphic section. Asymmetric folds (too small to be mapped) are found in the 100-foot competent (and thinly bedded) limestone unit near the base of the Boysen formation (Fig. 10). The mid-canyon flexure (Fig. 4) and the Buffalo Creek Canyon flexure typify the asymmetric anticlines of the Bighorn Basin. Red Canyon anticline is a feature of sufficient magnitude to be compared with Rattlesnake Mountain west of Cody (Fig. 2), though its flexing is not as pronounced. That a high-angle—or ramp— fault in the basement rocks underlies this particular structure seems highly probable.

If the upward slopes of the gentler limbs of the Red Canyon anticline and of the Buffalo Creek Canyon flexure represent directions of force application, one gets the impression of a pushing outward—

as along the rim of a lopsided shovel, the handle of which extends into the Bighorn Basin, and the blade of which points into the structural sag between the Bridger uplift on the east and the Owl Creek uplift on the west (Fig. 2).

The closer proximity of the Bridger (Copper Mountain) pre-Cambrian rocks on the east suggests a steeper slope for the basement rocks on that side, and coincidently the steeper limbs of the more abrupt monoclinal flexures face in that direction.

The most reasonable explanation for this series of flexures in the dip-slope area is to be found in a concept of basin mechanics within

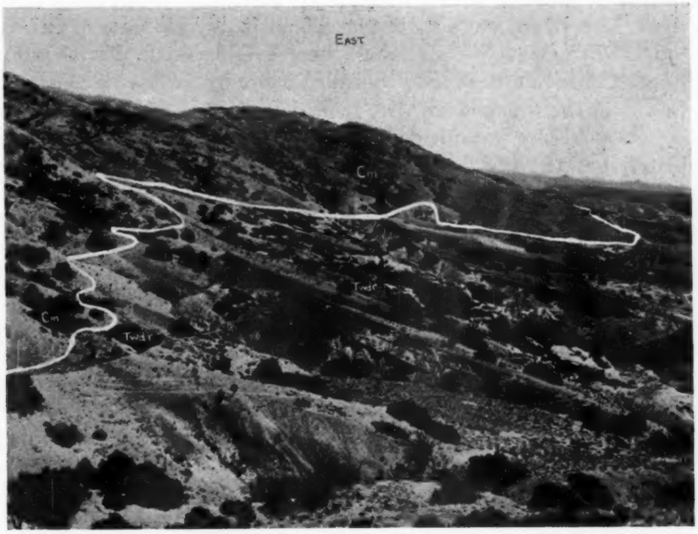


FIG. 23.—South front of mountains 3 miles east of Wind River, showing contact of Wind River formation with faulted zone. Dips and strikes of Wind River formation nearly parallel the slopes of exhumed mountain topography.

basin mechanics. If a series of discs are depressed in the center and lifted along the edges, not only do the higher layers tend to spread outward over the lower ones, but the rim also crinkles as the differential lift increases. The dip-slope area owes its structural pattern and type of deformation to the fact that it is on the trough of one of the wrinkles that developed on the edge of the major Bighorn Basin structure. Thus, in addition to the main near-surface and outward-directed forces operative as a result of the formation of the Bighorn Basin, there were local outward forces due to the minor peripheral downwarp that developed radially to the basin itself.

POST-LARAMIDE DEFORMATION

Deformation that occurred after the Laramide movements had ceased is limited to the slight flexures found in the overlapping Wind River formation of the Wind River Basin border area. These sediments so consistently parallel the mountain front (Figs. 4, 5, and 23), and formerly had so much overburden, that compaction suggests itself as the main causal factor for the observed post-Laramide deformational features, though post-Eocene warping and faulting may have contributed in a minor degree.

Investigations by Athy (1) indicate that initial dips may be increased by as much as 14° under the probable local overburden conditions. The Wind River sediments would have had some initial dip (up to a probable 5° maximum) sloping away from the mountain front. This would have been controlled more by the agents of deposition than the topography. The reflection of the topographic irregularities would have resulted after the overburden had compacted the material underlying that which is now exposed along the mountain front.

SIGNIFICANCE OF TECTONIC FEATURES

The major structural features of the Wind River Canyon area fit into the regional tectonic pattern (Fig. 2) as an example of inter-basin deformation. The dip-slope area is clearly a part of the Bighorn Basin, and the faulted zone represents a former extension of that basin's rim (Fig. 4). The Wind River Canyon area structures are so oriented because of the local resolution of regional compressive forces as the Bighorn Basin rim was shoved over the margin of the Wind River Basin.

The Boysen fault dies out west of the Wind River Canyon area, and farther west the Owl Creek Mountains have been thrust northward over the edge of the Bighorn Basin.

By contrast, east of the Wind River Canyon area, along the south front of the Bridger range, structures similar to those found in the canyon area seem to persist and may well be greater in magnitude of displacement. The Wind River formation blankets most of the deformed sediments south of the main Bridger massif, but has been stripped from two small islands of pre-Tertiary formations just south of the mountain front (Fig. 2). Both are mapped on the State geologic surveys as vertical or south-dipping Paleozoics, but a recent reconnaissance by the writer (1938) revealed this to be an incomplete and inaccurate portrayal. The smaller western island is composed of vertical formations ranging from Boysen to Cloverly in age (Table I).

The eastern island, known locally as "Steffens Hill," is made up of Paleozoic formations that are offset by more than one system of faults. It is bounded on the southern margin by exposed pre-Cambrian, overlain by Depass sandstone which dips southward beneath the overlapping Wind River beds. Both islands seem to be associated with major southward overthrust movements—indicating persistence of the situation found in the canyon area.

The tectonically dominant Bighorn Basin trends northwest-southeast, as do most of the structures within it. Its form is roughly oval, with an east-west trend evident along the Nye-Bowler lineament (41) at its northern margin and also along the eastern Owl Creek and Bridger mountains at its southern rim. The Wind River Canyon area is a section across this southern edge of the basin, where the structural trend is east-west, as is emphasized by the Boysen fault and the alignment of the faulted zone features, and southward overthrusting of 6-mile magnitude took place.

The particular location of the area on an east-west sector of the margin of the Bighorn Basin oval—which was under horizontal compression during Laramide time—is almost a sufficient explanation for the thrusting and east-west structural trends found there. The southward (or outward) direction of the overthrusting, however, is not the general rule for the Bighorn Basin rim, as may be seen in Figure 2. Locally it is presumed that the direction of overthrusting reflects a pre-Cambrian weakness control due to abrupt competency changes in a horizontal direction. Such competency variations would influence the asymmetrical developments when the arching of the Wind River Canyon region first began, and might well serve to determine the position of initial thrust planes.

That competency variations are important in localizing faulting is more definitely indicated in the case of the Boysen fault. At Boysen, incompetent schists are found against the fault plane in the upthrown block, but massive basic crystallines crop out a short distance north of the fault-trace (the position of the gully at Boysen in Figures 9 and 11 marks the contact between the schists and the more massive crystallines). Gwynne (19) suggests that the position of the fault was determined by the local presence of these incompetent rocks. However, a mile east of Boysen, where erosion has cut deeply enough to expose pre-Cambrian formations in the upthrown block, crystallines are found against the plane of movement.

Local eastward creep of the Bighorn Basin is suggested by the trace pattern of the faults that are adjacent to the Boysen fault on the south (Fig. 4). Such a creep may be explained in terms of the

Bighorn Basin, a dominant regional feature under horizontal compression during Laramide time, tending to elongate as the squeezing emphasized its oval shape. The northwest-southeast trend of the basin and most of its included structures reflects greater effective compression from the northeast and southwest, and—like a strain ellipse—it elongates at right angles to the confining forces. The Wind River Canyon area, and especially the Boysen fault, is on the particular part of the oval that would inch eastward.

The straightness of the Boysen fault is a characteristic common to many high-angle fractures in the region (Fig. 2). It is observed to have developed across incompetent schists at Boysen, but, if competency alone is taken as the causal factor, one is faced with the difficulty of explaining the rather geometric distribution of abrupt competency contacts to facilitate the faulting. It is suggested, rather, that a definite local competency change serves to initiate the faulting, and that—once begun—a sideward force component helps to maintain the straightness of the fracture in spite of competency variations along the developing fault plane. Such an explanation recognized the dual influence of stratigraphic competency and of differential forces set up as a region is being deformed by horizontal compression. The principle is understandable for the Boysen fault; it may apply elsewhere in the region.

Evidence on competency variations controlling the primary low-angle overthrusting is not available. The Boysen fault becomes more significant as an example of a fault that was partly due to definite competency changes in the pre-Cambrian formations—a factor that may be of great importance in explaining the development of the several "lobe-like thrusts" (Bucher, 9, p. 175) in the central Rocky Mountain region.

Wilson (42, p. 873) has recently re-outlined the pre-Cambrian fault and weakness-control explanation for the tectonic growth of the central Rocky Mountain region that was originally advanced by Thom (8). The weakness-control idea is well supported by the present investigations, but the writer finds no evidence in the canyon area that would lend support to the postulated presence of pre-existing fault planes in the basement rocks, outlining crustal blocks that tilt or rotate differently under compressive forces. Most of the thrusting in the canyon area preceded the formation of the straight, high-angle Boysen fault; the genesis of the Boysen fault was dependent on forces that developed as the local thrusting and regional deformation advanced. This suggests that pre-Cambrian weakness control rather

than fault control, was significant in the area. The forces causing other straight high-angle fractures in the Central Rockies may also be due to earlier near-by overthrusting that served to set up the requisite differential stresses.

SUMMARY AND CONCLUSIONS

In the central Rocky Mountain region, a sub-Cambrian peneplain was transgressed by epicontinental seas, with subordinate intervals of slight land emergence, until late in the Cretaceous period. Fluvial and lake deposits closed the Cretaceous and characterized Paleocene and later time, and local orogenic movements were slight until after the close of Cretaceous time.

The crust of the earth responded discontinuously to Laramide mountain-building forces, with varying results in each part of the region. General outlining of the basin areas took place with the earlier phases of the regional compression. This was followed by more intense phases of the Laramide compression, and the crustal readjustments by warping, folding and faulting ceased in some localities before they did in others. By mid-Eocene time the basin structures and their peripheral mountain rims had been formed. Later crustal movements, in the main, served to emphasize these structural highs and lows. At present, the Bighorn and Wind River basins are partly bounded by a relatively narrow rim of more ancient formations that stand as mountains by virtue of their greater resistance to erosion.

From observations in this thesis area (and from Figs. 2 and 4) it is clear that the southern part of the Bighorn Basin—locally symmetric in cross section—has been crowded relatively southward, and slightly eastward, with respect to the asymmetric Wind River Basin during Laramide time, and that this inter-basin competition led to the production of the large horizontal and vertical differential offsets of the pre-Cambrian basement complex. The south front thrusts developed and the toe of the overthrust mass broke off (forming the Boysen fault and most of the faulted zone structures) before the entire amount of crustal shortening had been completed. Coincidently, the deepening and decrease in radius of curvature of the Bighorn Basin, which occurred as the south rim of the basin was elevated relative to its center, led to the production of the Red Canyon anticline, the crests of slight flexure, the mid-canyon and Buffalo Creek Canyon flexures, minor asymmetric flexures in thin-bedded competent strata (see also Fig. 10), minor low-angle thrusts in the thick-bedded competent stratigraphic units (High Peak thrust,

Fig. 4), and a ramp thrust in the basement rocks beneath the Red Canyon anticline (*cf.* Rattlesnake anticline near Cody, section *AA'*, Fig. 2).

The double character of the main thrust planes (the south front thrusts and a deeper plane of movement) that developed as the inter-basin mechanical overlap proceeded, furnishes another example to indicate that this is not an unusual feature of rim thrusts in the general region. Comparison may be made, for instance, with the double thrust observable along the east front of the central Bighorns, and along the east front of the Beartooth uplift at Red Lodge.

This study of the Wind River Canyon area has indicated the primary and secondary structural features that were due to Laramide compression. The nature of the structural features which resulted from effective regional compression was largely controlled by the make-up of the rock section being deformed. The major regional compression was transmitted by the competent basement complex, and the major overthrusting was brought about in direct response to it; minor, nearer-surface, forces developed secondarily along with, and as a result of, the growth of the larger basin feature, and produced the intra-basin structures. Significant in this connection are the following: the horizontal equality and vertical variations in competence above the basal Cambrian unconformity (see Table II); the dominantly competent basement complex, with competency variations *not* horizontally arranged; the bedded or unbedded character of the rock units; and the probability of pre-Laramide lines of weakness defining and controlling the earlier basin and rim developments and influencing the later development of thrusts, folds, and normal faults in this inter-basin rim area of crustal deformation.

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GEOLOGY OF BASIN FIELDS IN SOUTHEASTERN ILLINOIS[1]

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ABSTRACT

The Basin fields of southeastern Illinois are so named because of being located near the center of the Illinois basin. Production has so far been obtained in Wayne, Clay, and Richland counties in a series of fields extending 45 miles in a general north-south direction. It is highly improbable that the producing areas will be found to connect.

Production was discovered in March, and active development was started in May, 1937. The production from the area to July 1, 1939, was 18,159,275 barrels from 692 wells. Daily average production at that time was 57 barrels per well. Large initial productions are common, and decline is rapid for the first few months. Twenty-acre spacing is prevalent.

Production is from oölitic limestone of the Ste. Genevieve formation (McClosky) except in the North Noble field, where it is from the Cypress (Weiler) sandstone, the former being in the upper part of the Lower Mississippian and the latter in the lower part of the Chester series.

The Cypress is a widespread sandstone but locally subject to lensing into beds of sands and shales. It is believed that Chester sandstone production will become more important as development extends northward. The oölitic character of the Ste. Genevieve is persistent in the area; however, porosity occurs in lenses of variable proportions laterally and vertically. Approximately 10 per cent of the holes drilled within the limits of production are dry because of lack of porosity in the limestone. Porosity is more persistent on the structures than in the synclines. Most of the McClosky porosity is believed to be primary in origin.

All except the Flora field are associated with a general north-south anticline, which has a slight southward plunge into the deeper part of the basin. Accumulation has for the most part been on local closures along the axis, but some production has been obtained from noses and terraces on the flanks on the main feature.

Little is known of the pre-Mississippian structural history. The known period of major deformation was post-Mississippian-pre-Pennsylvanian, but subsequent to this there was recurrent folding.

The relation of the contact of the Ste. Genevieve to the overlying Chester is controversial. However, the data do not indicate an angular unconformity at this contact in the deeper part of the basin.

Small production has been obtained from pre-Mississippian beds on the east and west flanks of the basin; however, since no test below the Mississippian has so far been drilled on structure in the area under consideration, the possibilities for deeper production are highly speculative.

INTRODUCTION

LOCATION

The area under discussion includes parts of Wayne, Clay, Richland, and adjacent counties in southeastern Illinois and is approximately 75 miles long and 30 miles wide. St. Louis is 130 miles west, Chicago 230 miles north, and the old historic Fort at Vincennes,

[1] Read before the Association at Oklahoma City, March 24, 1939. Revised manuscript received, August 8, 1939. Published with the permission of Theron Wasson, chief geologist, The Pure Oil Company.

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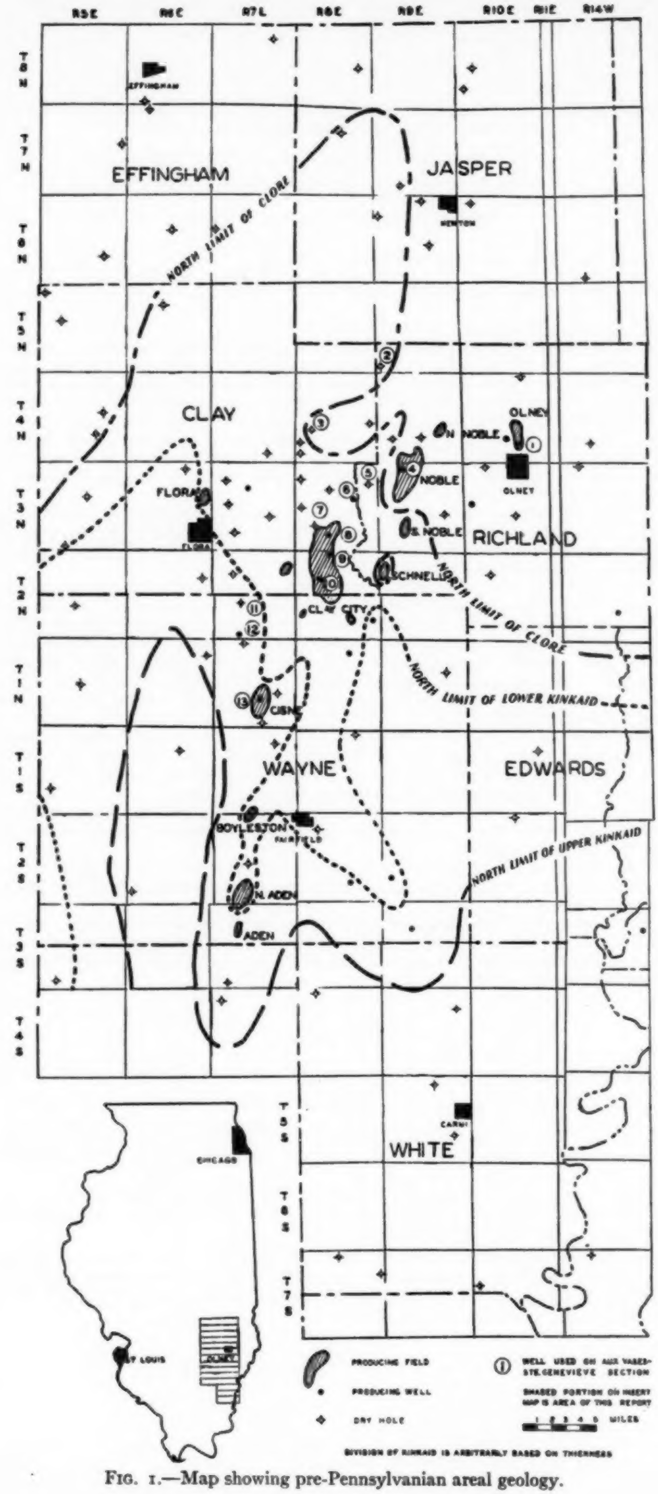

Fig. 1.—Map showing pre-Pennsylvanian areal geology.

Indiana, is 30 miles east. The main towns of the area are Olney, Flora, Fairfield, and Newton, in Richland, Clay, Wayne, and Jasper counties, respectively.

Because the axis of the Illinois basin passes through the counties under discussion, the new fields which have been developed in them have become known as the Basin fields to distinguish them from the old production in eastern Illinois on the LaSalle anticline and from the production recently developed in the western part of the state. The structure with which this production is associated has been designated the Basin anticline. The main fields so far developed are the North Aden, near the Wayne-Hamilton County line in T. 2 S., R. 7 E.; Cisne, Boyleston, and Enterprise, in central Wayne County; Clay City, in southern Clay and northern Wayne counties; Noble, North Noble, and Olney, in Richland County. There are small pools at Flora, Schnell, South Noble, and Aden. The outline of the developed part of the fields and pools and the location of the more recent discoveries, as well as the dry holes in the area, are shown on Figure 1. It can be seen that the production, with the exception of Flora, extends in a direction slightly east of north and west of south in a belt approximately 45 miles long. It is associated with a general anticlinal belt which will be discussed later.

DEVELOPMENT

Production was discovered in the area in March, 1937, by two wildcats drilled by The Pure Oil Company in what are now the Cisne and Clay City fields. These first discoveries were from the Aux Vases and the Cypress sandstones, respectively, and the wells were small. In May of that year the same company discovered relatively large production in the Clay City field from the "McClosky" limestone of the Ste. Genevieve formation. Development has progressed steadily since that time, most of the production being obtained from the McClosky with the exception of the Cypress production in the North Noble field. To July, 1939, 692 producing wells had been completed from which 18,159,275 barrels had been produced. At that time the daily production was 57 barrels per well. There have been approximately 14,200 acres proved productive to date. Production data of the various fields are shown in Table I.

In the McClosky initial productions have been as large as 2,800 barrels, the average for all producers being approximately 500 barrels. Average production declines are on the order of 30–35 per cent per month for the first 6 or 8 months, most of the wells having to be pumped within 4–8 months after completion. The decline is, of course,

less after this period, but there are not sufficient data to permit accurate extrapolations as yet. Initial productions from the Cypress sand in the North Noble field average approximately 200 barrels. The production decline of these wells is much smaller than in the McClosky wells, but this production is too new to permit any definite statement at this time.

TABLE I

PRODUCTION DATA AS OF JULY 1, 1939

Name	*Discovery Date*	*Number of Producing Wells*	*Developed Acres*	*Average Pay Thickness (Feet)*	*Accumulated Production Barrels*	*Present Daily Production (Barrels)*
Clay City	March 1937	293	6,200	12	8,647,144	22,247
Cisne	March. 1937	45	1,020	10	1,372,884	2,457
Noble	July 1937	162*	2,920	10	5,495,573	2,257
Olney	February 1938	31	470	7	562,953	744
South Noble	February 1938	10	440	5	159,002	350
North Aden and Aden	May 1938	48	940	12	818,486	2,052
Schnell	June 1938	4	180	5	111,929	129
Flora	June 1938	11	200	7	144,026	503
Leech	August 1938	2	50	7	29,924	113
North Noble	October 1938	37	540	20†	314,328	1,873
Boyleston	December 1938	11	300	7	36,176	530
Enterprise	January 1939	24	780	10	306,495	4,776
Barnhill	February 1939	6	160	12	72,581	1,511
Miscellaneous		8			87,774	122
Total		692	14,200		18,159,275	39,664

* Includes 4 abandoned producers.
† Cypress (Weiler) sand.

The first few wells in the Clay City field and the majority of the wells in the North Aden field were drilled on 10-acre spacing, but all other McClosky development has been on 20-acre spacing. The Cypress sand is being developed on 10-acre spacing.

STRATIGRAPHY

PENNSYLVANIAN

The Pennsylvanian is encountered below a thin veneer of Pleistocene and ranges from 2,000 to 2,300 feet thick. No detailed work has been done on the subsurface Pennsylvanian in this area, consequently it is impossible to subdivide it into its component parts. The section is mostly sandstone and shale with minor amounts of limestones and coals. All of the beds appear to be lenticular, and routine examination of samples has disclosed few markers which can be identified over broad areas. The most reliable marker so far found is a zone of limestone, black shale, and coals, which is found between 1,300 and 1,400 feet at Clay City and Noble. At its maximum development it is approximately 150 feet thick; however, the limestone and black shales grade laterally into sandstones and gray shales, and in many places the zone is less than 50 feet thick. This is probably in the lower part of the Carbondale immediately overlying the Pottsville sandstone.

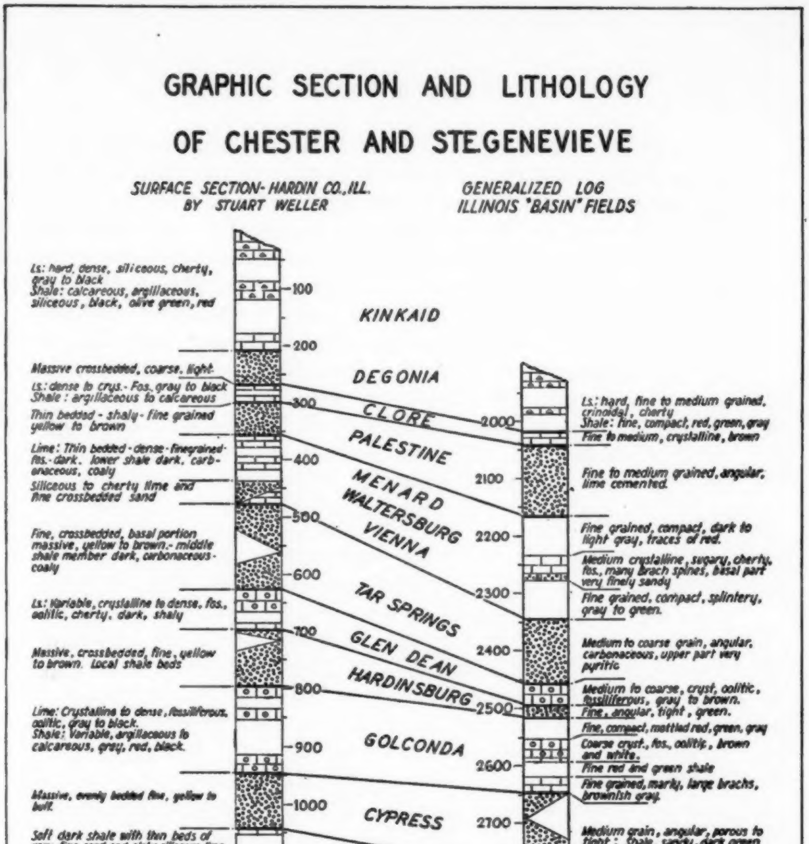

FIG. 2.—Graphic section and lithology of Chester and Ste. Genevieve.

According to Newton and Weller[3] the Upper Pennsylvanian crops out in Jasper and Richland counties. These same rocks probably also occupy the greater part of Clay and Wayne counties.

The base of the Pennsylvanian is placed where the sands lose their micaceous and sideritic characteristics and/or where the shales cease to be micaceous, carbonaceous, and granular, and become compact, splintery and "soapy." There is an unconformable contact between the Pennsylvanian and the underlying Chester rocks, and the former overlaps the latter section from the upper Kinkaid to the Menard in the area under discussion. As can be seen in Figure 1, this overlap is in general from south to north; however, the Basin anticlinal belt is reflected in the pre-Pennsylvanian areal geology by an interruption of this normal overlap.

CHESTER

The Chester rocks of the area consist of a number of limestones, shales, and sandstones. The limestones, which are well developed, make good horizon markers. Figure 2 shows an idealized log for the area as correlated with the measured section in Hardin County as given by Weller.[4] The principal lithologic characteristics of the various Chester beds also are shown. It can be seen that the subsurface section correlates well with the surface section except for the basal formation of the Chester, about which more will be said later. A detailed discussion of all of these beds is not within the scope of this paper; however, some of the more important horizons will be discussed.

The Glen Dean formation contains a limestone 20–30 feet thick, which is commonly used as a contour horizon for subsurface mapping. This limestone has an advantage for this purpose over the other Chester limestones for several reasons: it is far enough below the top of the Chester to be present under a large part of the Illinois basin without interference by the Pennsylvanian unconformity; it is approximately 200 feet above the Cypress, which permits its use in connection with the drilling of Cypress sand wells; and it is lithologically distinct from most of the other Chester limestones. In general the Glen Dean limestone is light brown to gray, crystalline, very fossiliferous, and oölitic. Thin limestone beds are sometimes present in the upper part of the formation which cause some confusion in identifying the main limestone; however, it generally can be identified quite satisfactorily.

[3] Wm. A. Newton and J. Marvin Weller, "Stratigraphic Studies of Pennsylvanian Outcrops in Part of Southeastern Illinois," *Illinois State Geol. Survey Rept. Investig. 45*.

[4] Stuart Weller, "The Geology of Hardin County," *Illinois State Geol. Survey Bull. 41*.

The Cypress sandstone is the uppermost producing zone so far drilled in the area. The top of it is defined as being the base of the lower Golconda limestone because of the variability in the lithology of the Cypress. While this formation is often a massive sandstone with a thickness ranging from 120 to 175 feet, it is capable of grading laterally into beds of sandstones and shales, and the upper half has been known to become entirely shale. These gradations occur in very short distances and are shown both by the samples and electric logs. Because of this situation, it has become common practice to call the top of the porous sandstone phase the "Weiler" sand to differentiate this from the true top of the Cypress formation. This name was adopted from the discovery well in the Clay City field on the Weiler farm, which produced from this sandstone.

Showings of oil in this sandstone are common along the Basin anticline; however, the North Noble field is the only area producing from it, the original well at Clay City having been deepened to the McClosky. In the North Noble field 20-30 feet of shale is present below the basal Golconda limestone, which is followed by the oil-producing sand with a thickness varying from 6 to 33 feet. The producing sand is separated from the massive sand body below by approximately 20 feet of green shale which contains thin non-porous, sandy shale partings. The producing sand thickens and thins inversely with the shale above it. It is probable that this upper sandstone will not be found in part of the North Noble field, and in other parts all of the shale may disappear, making the section all sand. There is no bottom water in the lens in which the present wells are producing, and present development has not shown edge water. The lower sand has contained water in the three wells so far drilled to it, but showings of oil in the top suggest that it may produce when found higher on structure.

Permeabilities in the upper sand vary between 10 and 600, probably averaging 300 millidarcys, and the lower sand has up to 3,000 millidarcys. Average porosity is on the order of 20 per cent.

The Bethel or Benoist sand is 370–400 feet below the Glen Dean limestone. The thickness of this sandstone varies from 20 to 70 feet along the Basin anticline and apparently thickens from south to north. In general it is a fine to medium-grained, angular, fairly well calcareous-cemented sandstone. Large production is obtained from this sand in the Salem and Louden fields west of this area, as well as along the LaSalle anticline; however, so far only a few showings of oil have been encountered from it in the deeper part of the basin.

AUX VASES

The Chester section, as considered in this paper, differs from that of Hardin County in that the basal formation is essentially clastic

and is correlated with the Aux Vases sandstone of Ste. Genevieve County, Missouri, whereas in Hardin County the basal Chester member, as correlated by Weller,[5] is the Shetlerville limestone and shale. The Aux Vases formation consists of three members of the basin. The upper member is a fine-grained, muddy-appearing sandstone. The middle member is sandy, oölitic limestone, the oölites generally being colored, and in the well samples they stand out in relief. This member resembles the Rosiclare sandstone. The lower member is characteristically calcareous, fine-grained sand with variable amounts of limestone or dolomite, which are fossiliferous, sandy, and oölitic. Bryozoa are common, and in some localities the limestone appears to be a reef type. The oölites are generally colored, commonly red, and the limestone is sandy and argillaceous. The limestone is ordinarily dolomitized, the oölites reduced to shadows, and in a few places contains erratic pebbles as large as $\frac{1}{4}$ inch in diameter. In some wells this limestone very closely resembles the oölitic part of the Fredonia, and, since the overlying member is similar to the Rosiclare, it is apparent that correlations are difficult where this occurs, and some confusion has resulted. The brown, crystalline limestone of the Lower O'Hara, which is discussed later, has to be assumed to be missing to make this correlation; however, so far as the writer knows, no well yet has been drilled in the basin which did not have this limestone represented below the confusing Aux Vases section.

The Aux Vases as described here is lithologically very similar to the Hoffner member of the Ste. Genevieve as recently described by Weller and Sutton.[6] The correlation of the Hoffner as a part of the Ste. Genevieve is based on fossil evidence. The subsurface correlation of the Aux Vases as used in this paper is based on the premise that this clastic formation has a closer relation with the Chester series than with the Ste. Genevieve limestones. More work should be done on both the subsurface and surface sections before either of these correlations should be accepted as definite.

The upper Aux Vases sand produces in the discovery well at Cisne. The lower sand and dolomite produce in two wells in the Clay City field, one in the Noble field, and in two wells between these fields. The production is small and very erratic.

STE. GENEVIEVE LIMESTONE

The Ste. Genevieve limestone is the most important producing formation of the area and has, therefore, been studied in detail by

[5] Stuart Weller, *op. cit.*

[6] J. Marvin Weller and A. H. Sutton, "Mississippian Border of Eastern Interior Basin," manuscript presented before the Association at Oklahoma City, March 24, 1939.

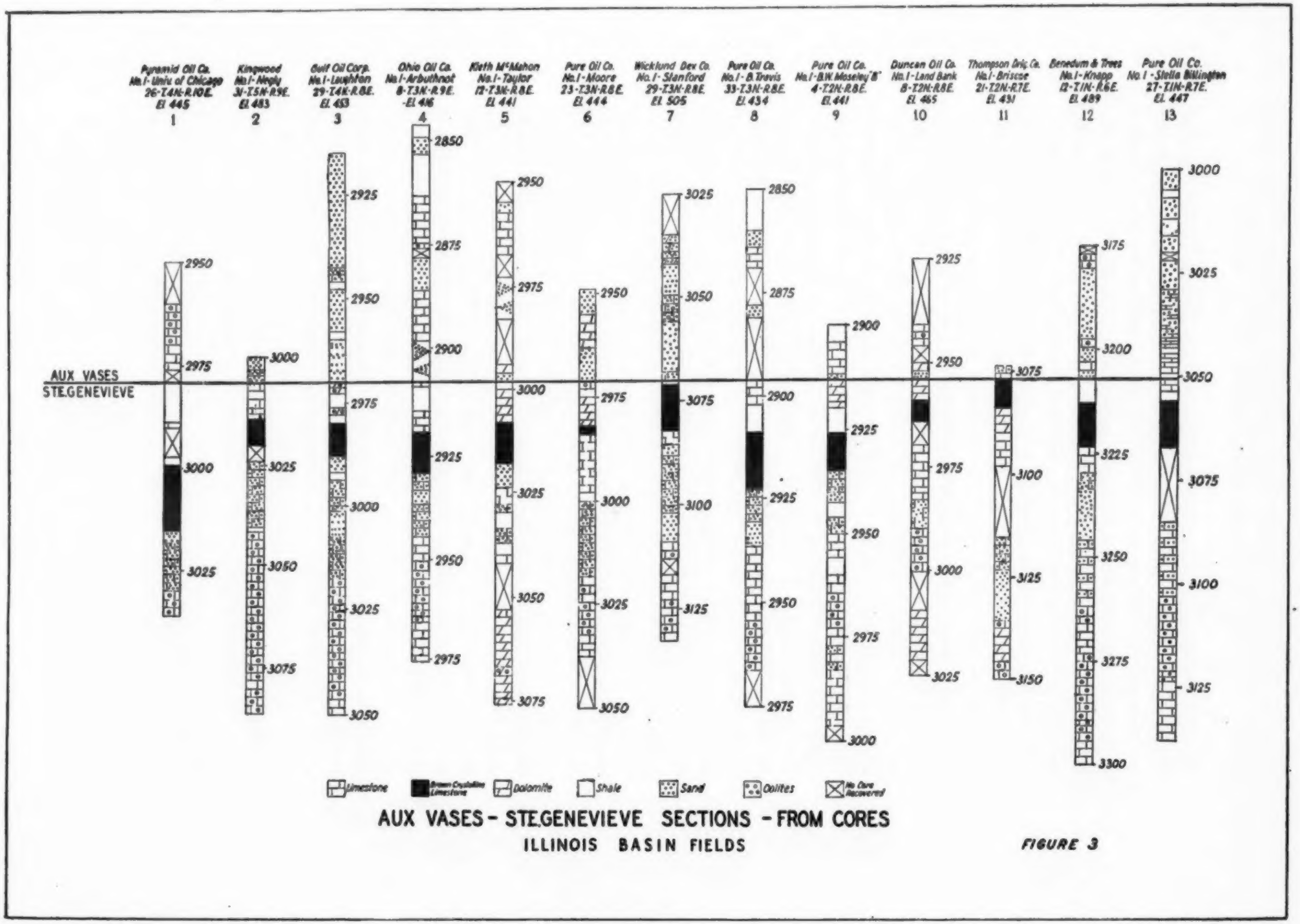

FIG. 3.—Aux Vases-Ste. Genevieve sections—from cores.

more geologists than other parts of the section. The correlation of the top of the formation, as well as its relation with the overlying beds, is controversial. This is to be expected, for in addition to the similarity to some of the Aux Vases beds, the subsurface correlation is made on the basis of lithology, whereas Weller's[7] correlation of the nearest outcrop in Hardin County, Illinois, with that of the type locality in Ste. Genevieve County, Missouri, was made on the basis of fauna. The top of the Ste. Genevieve as defined in this report is placed at the base of the clastic material overlying a brown, crystalline, fossiliferous limestone which is persistently present. Figure 3 shows the detailed lithology of the section immediately above and below the brown, crystalline limestone, as revealed from cores in wells generally distributed throughout the area. This section indicates that there are three divisions of the Ste. Genevieve which lithologically compare with the three divisions described by Weller[8] in Hardin County. The upper zone is believed to be the equivalent of Weller's Lower O'Hara. Its most common development is thin gray, sugary dolomite, below which is green, compact, fossiliferous shale, followed by brown, crystalline, fossiliferous limestone. All three of these beds vary in thickness and to a certain extent in lithologic characteristics. The brown crystalline lime is the most readily recognized; however, in some places it is dolomitized to such an extent that its original characteristics are masked. The thickness of this zone varies from 15 to 35 feet in the cored sections shown.

This sequence is followed by a sandy zone correlated with the Rosiclare sandstone, which is characterized by its poorly sorted sand grains and dark, large oölites which have a tendency to stand out in relief in the sample chips. There are lateral differences within this zone as demonstrated by variation in the thickness and number of shale beds and by the variation in the size of the sand grains from one well to another in short distances. In some wells the sand in this zone is so fine that it is difficult to detect, yet digestion in acid will reveal sand content as high as 50 per cent. In other wells the sand is coarse and conspicuous. Within this zone beds of fairly pure oölitic limestone occur. Production has been obtained from one such bed in 5 wells in the Clay City pool. In the cored sections shown, this sandy zone has a minimum thickness of 7 feet and a maximum thickness of 30 feet.

The lowest and thickest member of the Ste. Genevieve is the Fredonia. The upper part of this member is generally pure limestone,

[7] Stuart Weller, *op. cit.*

[8] *Ibid.*

characterized by large and numerous oölites. The oolitic beds become thinner, and dense dolomite and limestone beds become more prominent in the lower part of the Fredonia.

When examined in detail considerable lateral variation can be found in the lithology of the Fredonia. In wells in which the porosity is developed in the oölitic zones, the limestone matrix is pure calcium carbonate in contrast to a fair sand content in the same zone where the porosity is not developed. This sandy development is not to be confused with regenerated quartz crystals which are commonly present. Dense, soft, chalky dolomites come and go in the section, and 40–50 feet below the top of the Fredonia in the basin, as well as on the outcrop, sandstone similar to the Rosiclare is locally but not everywhere present. The base of the Ste. Genevieve is arbitrarily placed at the top of the heavy chert beds, which are believed to be in the underlying St. Louis. There is generally thin, fine, sandy limestone immediately above the chert contact.

The variations in thickness and lithologic characteristics of the Lower O'Hara have caused much speculation, and any theory suggested to explain them meets with objections and is difficult to prove. It has been postulated that an angular unconformity exists in the basin at the base of the Chester as observed by Weller[9] in Hardin County. The principal evidence in favor of this is the occurrence of erratic fragments in some of the overlying beds where these beds are limestones. The writer has no basis for discounting the existence of an angular unconformity on the outcrop but believes it is unnecessary to place such an unconformity in the deeper part of the basin. There actually may be a break in deposition, but the fact that the Lower O'Hara is present in all wells cored, regardless of structural position, even though it is a thin member, indicates that no erosion took place. The variations in thickness and lithologic characteristics of the Lower O'Hara are no greater than in the Rosiclare and Fredonia. Although these variations are conspicuous in Figure 3, they are more apparent than real as the vertical scale has been greatly exaggerated in order to show detail, and only the typical, brown, crystalline limestone has been emphasized.

The variations in thickness of the Rosiclare member and in the lithology of the underlying Fredonia have caused some students to place an unconformity between these members. The writer believes that these characteristics are caused by lateral depositional variations in the Ste. Genevieve which are to be expected with the probable conditions under which it was deposited. The upper part of the Lower

[9] Stuart Weller, *op. cit.*

Mississippian limestone was deposited in a closed basin which was subject to periodic desiccation as suggested by the introduction of dwarfed fauna in the Spergen, anhydrite beds in the St. Louis, and abundant oölites[10] in the St. Louis and Ste. Genevieve. In such a basin minor factors of deposition will have a decided effect on the resulting rock, and lateral variations, such as observed in the Ste. Genevieve, could result even though deposition was continuous.

Most of the Fredonia "pays" occur within 70 feet of the top. Where the porosity has its maximum development, it generally occurs in a continuous zone with possibly one or two thin stringers of tight limestone within it. The reduction in thickness of the porosity is apparently gradational and is due to an increase in number and thickness of the tight limestone stringers at the expense of the porous zone. This transformation can take place in offset locations, but generally is more gradual. Thin pay zones occur in a few places down to 100 feet in the Fredonia, and here and there an erratic, thin zone is present between 100 and 150 feet in the formation. The maximum pay thickness of the McClosky is about 30 feet, and the average for the principal fields is approximately 15 feet.

Except in a few isolated places, bottom water is not present, and in the Clay City and Noble fields there is no edge water in the McClosky. The limits of production in these fields are defined either by absence of porosity or by the low structural position of the wells. In the Cisne and North Aden fields there is evidence that edge water exists; however, at Cisne it is very erratic, and the reservoir may be essentially under volumetric control. This may also be true at North Aden, but the wells have not been drilled in such a manner as to demonstrate it.

The writer believes that most of the McClosky porosity is primary in origin. Microscopic examination of many cores does not reveal any evidence of solution on the surfaces of the oölites, and the porosity is of the interstitial type very much as in sandstones. There is, as a matter of fact, evidence that some of the oölitic zones are tight because of secondary deposition of calcite or dolomite in the interstices. Microscopic carbonate crystals are attached to many of the oölites in wells with good permeability, and in less permeable sections the interstices are filled with similar but larger crystals. Where stylolite seams are present within a porous zone, the interstices are filled with these crystals, making the limestone impervious for 6 or 8 inches below and above these seams. Vertical fractures up to 15 feet long

[10] A. J. Eardley, "Sediments of Great Salt Lake, Utah," *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 22, No. 10 (October, 1938).

and ¼ inch wide, which have been healed by calcite, are common in the Fredonia. These deposits must have been due to circulating waters after initial deposition.

Porosity is more consistently developed in the McClosky along the anticlinal belt than it is in the synclines on the east and west. Insufficient study of this has been made by the writer to attempt an explanation at this time.

PRE-MISSISSIPPIAN

No tests have been drilled in the Basin fields below the St. Louis formation. Small production from pre-Mississippian beds has been obtained on the flanks of the Illinois basin and on the LaSalle anticline; however, the prospect of obtaining production from these beds on the Basin anticline is highly speculative. It is estimated that the Devonian limestone will be found in the Clay City field at approximately 4,500 feet, the Trenton limestone at 5,900, and the St. Peter sandstone at 6,600 feet.

STRUCTURE

As previously stated, the axis of the Illinois basin extends north and south approximately through the middle of the area. This axis has a southward plunge, and the deepest part of the basin in Illinois is in northern Hamilton and White counties. The basin is traversed by a low, broad, anticlinal belt with the main axis extending slightly east of north and west of south as shown on Figure 1. This anticlinal belt has a southward plunge amounting to approximately 400 feet from northern Richland County to southern Wayne County. In the northern part of the area the anticline is a simple structural ridge, but toward the south the belt becomes much broader and resolves itself into several anticlinal axes with their attendant synclines. Along these axes local reversals exist, resulting in closures of the magnitude of 100 feet as mapped on the Mississippian beds, on which most of the production is located. The Olney field is located on a nose extending off the main structure, and the Flora pool is apparently on a relatively small local structure.

STRUCTURAL HISTORY

Isopach maps indicate that the basin was open toward the south until the close of Mississippian time at least to the latitude of the Shawneetown-Rough Creek fault. The thickest Mississippian sections so far drilled in Illinois have been encountered in the Ohio Oil Company's Hancock No. 1 in Sec. 4, T. 11 S., R. 5 E., Pope County, and in the Leach Brothers' Ellen No. 1 in Sec. 3, T. 2 S., R. 10 E., Edwards

County, being 2,468 feet in the former and 2,426 feet in the latter. It is reasonably certain, however, that south of the Ellen well this section thickens, as wells drilled in Union County, Kentucky, and southern Posey County, Indiana, have encountered 400–500 feet of additional Mississippian section. The Mississippian sections in Hardin County, south of the Rough Creek fault, as measured by Weller,[11] are 100–200 feet thinner than the wells referred to in Indiana and Kentucky. This thinning suggests that the Mississippian basin was closing toward the south at the latitude of the Rough Creek fault and/or this fault influenced deposition.

Little is known of the pre-Mississippian structural history of the Basin anticline since no wells have been drilled on it below the St. Louis limestone. The Mississippian structure as mapped from well data coincides with the Devonian structure mapped on seismic data, indicating that there was no pronounced folding during Mississippian time.

The most pronounced period of folding known to exist occurred at the close of Mississippian time and before Pennsylvanian deposition. After this folding the surface was exposed to erosion and apparently almost base leveled as Pennsylvanian overlaps beds of Chester age. Figure 1 shows the areal geology at the time of initial Pennsylvanian deposition. The west dip of the anticlinal belt is clearly shown. The east dip is not as obvious, due to the Pennsylvanian unconformity cutting as deeply into the Chester beds in the eastern syncline as it did along the top of the structure; however, the base of the Pennsylvanian and the Mississippian beds are 200–300 feet lower structurally than on the anticline. This syncline lies between the Basin anticline and the LaSalle anticline and could well have been the drainage area for these positive features, permitting it to be eroded deeper than the top of the Basin anticline as peneplanation was approached.

The Middle Pennsylvanian zone of limestone, coal, and black shale, previously mentioned as occurring in the Clay City and Noble fields, reflects the structure; however, the dips are much less pronounced than in the Mississippian beds, and the axis shifts to the east. Newton and Weller's[12] work on the surface beds of Upper Pennsylvania suggests the presence of the structure in a general way by the pattern of the areal geology. From this it is concluded that there was recurrent folding on a minor scale during and subsequent to Pennsylvanian time.

[11] Stuart Weller, *op. cit.*

[12] Wm. A. Newton and J. Marvin Weller, *op. cit.*

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SIGNIFICANT UNCERTAINTIES IN PENNSYLVANIAN CORRELATION IN ILLINOIS COAL BASIN[1]

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ABSTRACT

In connection with the preparation of coal-bed structure maps stratigraphic studies have been made based on the matching of drilling logs of a series of wells extending from the vicinity of Carlinville on the west to western Cumberland County on the east. Such studies reveal a lack of agreement with correlations based on the study of outcrops. The pattern of succession on the western margin of the basin produced by the spacing of important limestone and coal beds appears to be traceable into the central part of the basin, indicating that the surface beds in the central area are much younger than those on the margin. Such a conclusion is at variance with conclusions that have been recently reached by the study of outcrops independent of coal-bed structures. Such studies have resulted in correlations which require a conspicuous spreading between the prominent limestone beds as they approach the inner part of the basin, resulting in a marked departure from parallelism with coal bed No. 6 on the part of the higher limestones. The paper points out the need of further studies and elaborates the evidence on which surface correlations are based.

For the better part of three decades the writer has given the major part of his attention to the geology of the coal beds of Illinois. His interest has been centered on the economic aspects of the coal beds as mineral resources to be explored, mined, and utilized. A large amount of time has been devoted to the delineation of the position of outcrop of the workable coal beds, in a study of their variations in thickness and their chemical and physical characteristics, and in mapping their structural features. Necessarily in such mapping projects, since the coal beds are usually at considerable depths, in some places 1,000 feet or more, much dependence has been placed on drilling records in determining their extent and position.

Within the main coal-mining districts the identification of the workable coal beds in Illinois is based on familiar peculiarities of the individual beds, the spacing of the beds in the Coal Measures, and the relationship of the coal beds to other widespread and recognizable units, such, for example, as the cap-rock limestone of Herrin (No. 6) coal bed. Away from the regions where the coal beds have been mined or closely explored, the correct identification of a coal bed is not everywhere apparent, and reliance for identification is placed on the usual procedure of stratigraphic correlation. The economic geologist is therefore not uncommonly dependent on the stratigraphic geolo-

[1] Presented at Geology Section, Milwaukee Meeting, A.A.A.S., June 21, 1939, by permission of the chief of the Illinois State Geological Survey. Manuscript received, July 8, 1939. Published with the permission of the chief of the Survey but representing the author's individual opinion.

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gist, or on such facts in regard to the stratigraphic succession as he can himself decipher from the drill logs for identification of coal beds outside the mining districts.

Had the knowledge of Pennsylvanian stratigraphy kept abreast, or better, a little ahead of the growing need for that knowledge in preparing fuel-resource inventories, the economic geologist would probably now be able to interpret drilling data on the basis of sound stratigraphic information; at least this would apply to such records as are reasonably accurate. Unfortunately, the details of our Pennsylvanian succession are so inadequately understood that a great deal of dependence in interpretation is still placed on nimbleness, ingenuity, and shrewdness in log matching for the purpose of discovering regular patterns and spacing in the succession. Such regularity when discovered has been taken to indicate continuity of beds, even though the identity of such beds may be uncertain.

The great superiority of systematic stratigraphy over log matching is readily admitted, since it requires very little geological knowledge to make such comparisons, but it should likewise be realized that danger of error in correlation and identification of beds also exists when stratigraphic studies based on outcropping beds give no consideration to the facts in regard to the structure as revealed by drilling.

One of the principal activities of the Coal Division of the Survey has been the mapping of the structure of the workable coal beds of the state. During the last 10 years or more attention has been directed particularly to the delineation of the structure of Herrin (No. 6) coal for a large part of the southern half of the Illinois coal basin. In large areas in southwestern and southern Illinois drilling has been fairly closely spaced and much of it has been done by coring devices. In general, in this area the tracing of the coal bed from drill hole to drill hole is mainly based on the altitude and thickness of the coal bed. Away from the mines, however, and the more closely spaced drill holes, more care in identifying the coal bed is necessary, and the details of the drilling records become important.

In preparing structure maps the economic geologist finds it necessary to familiarize himself with the stratigraphic succession revealed by the drilling logs. He may be working in an area where the coal bed is many hundred feet below the surface so that most of the beds penetrated in drilling are exposed only at places remote from the area being studied. Unless the stratigraphy is thoroughly understood, which is rarely the fact in Illinois, the geologist will find it impossible

to interpret his drilling data in terms of standard stratigraphic units. Instead he will seek to discover beds of apparent continuity in the area by matching log with log and thereby work out a sort of stratigraphic pattern that seems to prevail. Such a stratigraphic pattern can then be used as a standard for identifying a coal bed or the position of a coal-bed horizon on the fringes of a coal-mining district.

It is almost inevitable, however, following such a practice, that there will be some effort made to give the individual units comprising the stratigraphic pattern the names of outcropping beds if relationships seem to be similar, although the exposure of such beds may be at considerable distance. These correlations will vary greatly in correctness, depending on the care exercised in making identifications. Experience has shown that many of them have been erroneous, particularly those made in the early years of the present Survey.

In general, in Illinois, surface and underground stratigraphy of the Pennsylvanian rocks has been carried on largely independently by different groups of workers, so that miscorrelations resulted in a number of instances. In general, Pennsylvanian strata encountered in drilling have not been systematically identified in the logs largely because the need for such identification has not been particularly pressing since the coal beds could generally be identified and followed by the log-matching procedure. With the recent discovery of oil fields in the coal basin, the stratigraphic identification of beds becomes of much greater importance in the interpretation of structure.

In the light of these remarks, the development of the present confusion in the correlation of a number of important members of the McLeansboro formation in the Illinois coal basin can probably be better understood. The nature of this confusion will now be considered.

Because of the emphasis that has been placed on the economic aspects of geological investigations by the Survey during its first ten years of existence, structural studies have proceeded much more rapidly than stratigraphic studies, in spite of the fundamental value of the latter. In the preparation of structure maps of coal bed No. 6 in southwestern and southern Illinois many hundreds of drilling logs were used to locate the position of the coal. These were generally studied in graphic form on a scale of 1 inch to 100 feet of vertical distance. Using such graphic logs the prevailing arrangement of beds of the McLeansboro formation for the southwestern part of the basin was worked out with little attempt to tie in known outcrops with strata penetrated in drilling except in two or three instances. The

outstanding distinctive units of the stratigraphic pattern based on log matching were described by Kay[3] in 1915 as follows (Fig. 1).

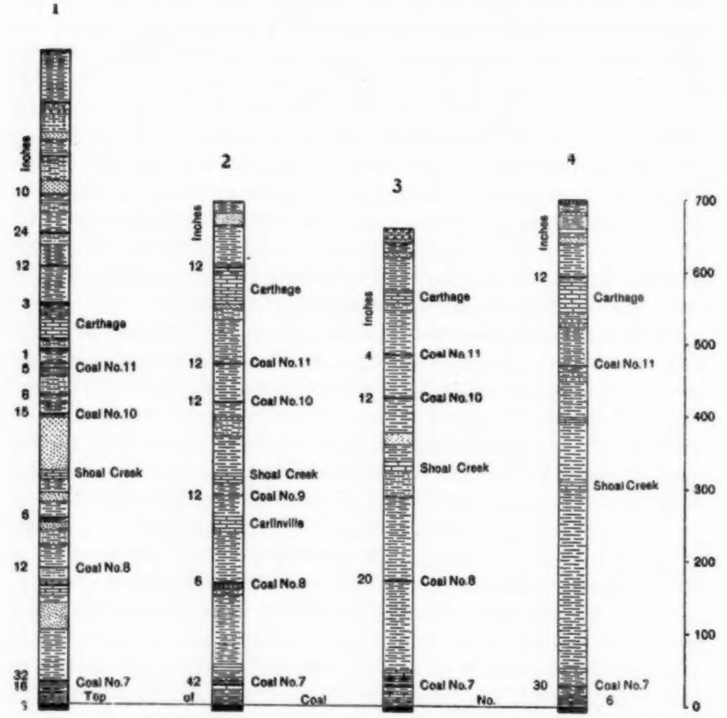

FIG. 1.—Sections showing persistent nature of limestones in McLeansboro formation (after Kay).
1. Lovington, Moultrie County.
2. Sec. 8, T. 10 N., R. 1 E., Shelby County.
3. NW. ¼, NW. ¼, Sec. 8, T. 9 N., R. 1 W., Montgomery County.
4. Sec. 29, T. 9 N., R. 1 E., Fayette County.

7. New Haven limestone, 200 to 250 feet above Carlinville limestone

6. Shoal Creek limestone, about 100 feet above Carlinville limestone

5. Carlinville limestone, so-called because of typical outcrops near town of this name in Macoupin County. Its position is from 200 feet to a little more than 300 feet above coal No. 6

4. Coal No. 8, ranging in thickness from 8 inches where present to 2 feet and lying 150 to 180 feet above coal No. 6

[3] F. H. Kay, "Coal Resources of District VII," *Illinois State Geol. Survey Coöperative Mining Investigations Bull. 11* (1915), p. 23.

3. A bed of pink, red, or variegated shale, variable in thickness, seldom exceeding 15 feet, averaging from 35 to 50 feet above coal No. 6

Wallace Lee[4] states that the Shoal Creek limestone lies 75 feet above the Carlinville. Kay calls a coal, lying a short distance below the Shoal Creek limestone, coal No. 9. He states that "the New Haven limestone is encountered in nearly every drill hole that reaches coal No. 6 at a depth of 700 feet or more," and in "most logs is given a thickness of at least 25 feet." Kay calls the limestone New Haven, but the basis of correlation is mainly the interval between the limestone cropping out at New Haven, White County, and coal bed No. 6, which is about 500 feet. At any rate, whether or not the limestone 500 feet above coal bed No. 6 in District VII is correctly identified as the New Haven, its existence must be conceded. Kay finds two fairly persistent thin coal beds which he calls No. 10 and No. 11 about 50–60 feet apart midway between the limestone he designates the Shoal Creek and the one he calls the New Haven.

This general pattern of the McLeansboro succession has been the basis for identifying the position of coal bed No. 6 in the central part of the basin for more than 20 years. The general sequence undoubtedly exists irrespective of the identification of the different beds. The identification used by Kay is largely adopted from Lee[5] and Shaw and Udden[6] following the systematic geological mapping of four quadrangles lying in Macoupin, Montgomery, Madison, St. Clair, and Clinton counties. This quadrangle mapping between 1907 and 1914 gave considerable weight to the identifications made by Kay, which, however, were based largely on the evidence supplied by drilling.

Since 1925, under the stimulation of a new theory of Pennsylvanian sedimentation and stratigraphy announced by J. M. Weller and H. R. Wanless about 10 years ago, the outcrops of Pennsylvanian beds in Illinois have been examined and mapped with renewed interest. As a result correlations have been proposed that are of particular interest because of their departure from long accepted ideas. These later investigators recognized in the McLeansboro formation of southwestern Illinois the following distinctive beds other than coal beds.[7]

[4] Wallace Lee, "Gillespie and Mt. Olive, Illinois," *U. S. Geol. Survey Geol. Atlas Folio 220* (1926), p. 6.

[5] Wallace Lee, *op. cit.*

[6] E. W. Shaw and J. A. Udden, "Belleville-Breese, Illinois," *U. S. Geol. Survey Geol. Atlas Folio 195* (1915).

[7] Harold R. Wanless, "Pennsylvanian Correlations in the Eastern Interior and Appalachian Coal Fields," *Geol. Soc. America Spec. Paper 17* (March 30, 1939), pp. 15–19.

5. La Salle limestone
4. Shoal Creek limestone which is correlated with the New Haven limestone at New Haven, White County
3. Lonsdale limestone, also identified as the Cutler limestone in southwestern Illinois
2. Piasa limestone, also identified as the Bankston Fork limestone in southern and southwestern Illinois
1. Herrin limestone, the cap-rock of coal No. 6.

It may be well to note especially that the Shoal Creek limestone of Kay and Lee is renamed the LaSalle limestone and that the Carlinville limestone of Kay and Lee is given the name Shoal Creek. The Shoal Creek limestone as revised is correlated with the New Haven limestone. Two additional limestones are listed, the Lonsdale and the Piasa which are correlated with two widespread limestones encountered in many logs and exposed at many places in southern Illinois. The upper or Cutler limestone is about 40 feet above the Herrin (No. 6) coal bed and is underlain by the Cutler coal bed, probably coal No. 7 of Kay. The lower or Bankston Fork limestone lies about 20–25 feet above the Herrin (No. 6) coal bed (Fig. 2). It is in places overlain by a thin bed of coal. This coal bed and the Cutler coal bed (No. 7?) which has a black sheety shale roof are commonly encountered by the drill in passing through the strata intervening between the Cutler and Bankston Fork limestones.

These two limestone beds were found by field parties of the Coal Division working in Saline, Randolph, and Perry counties between 1920 and 1930.

The two schemes of stratigraphic arrangement that have been noted, one dependent largely on the organization and comparison of drilling data and the other mainly on surface outcrops, are not in agreement in a number of particulars. Decision in regard to the accuracy of either, so far as the economic geologist is concerned, is for the present in abeyance. The bases for the uncertainty in regard to the identity and correlation of the more distinctive of these McLeansboro beds may well be explained in greater detail.

NEW HAVEN LIMESTONE OF KAY

What is the limestone designated by Kay as the New Haven (or Carthage) which the study of well records indicates overlies the Shoal Creek and Carlinville limestones as he identified them in the succession, if the limestone exposed at New Haven, White County, is correctly correlated with the Carlinville limestone of Kay and Lee?

Studies by Taylor and Prescott[8] indicate that such an upper lime-

[8] Unpublished paper read at Illinois Academy of Sciences, May, 1939.

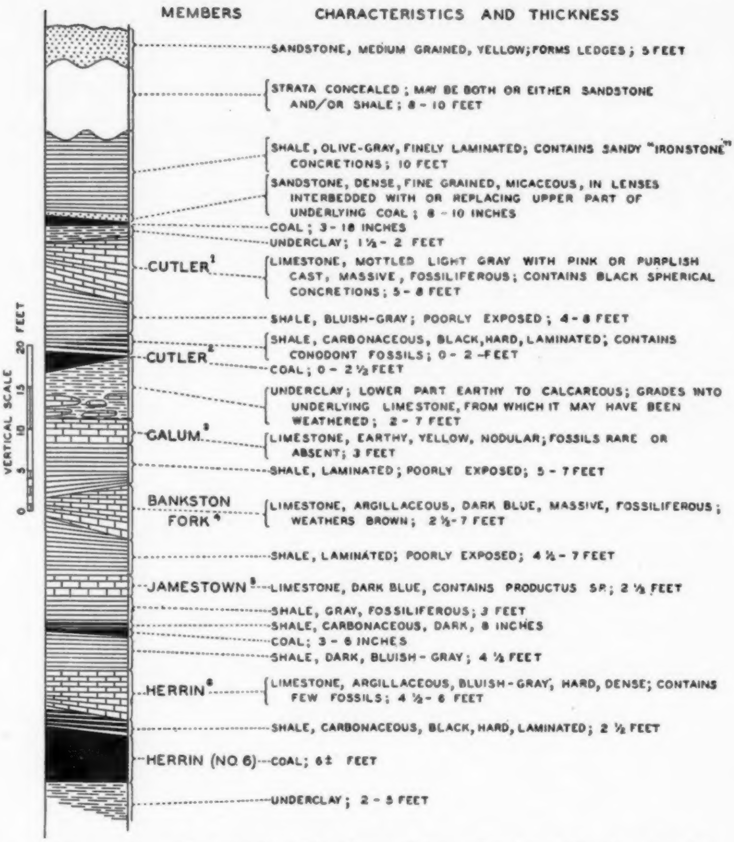

FIG. 2.—Generalized stratigraphic column of Pennsylvanian strata above and including Herrin (No. 6) coal in vicinity of Pinckneyville and Jamestown, as compiled from outcrops and records (after Ball and McCabe).

1. The name *Cutler* is applied to this limestone member because it is typically exposed in the vicinity of Cutler, Perry County, Illinois.
2. The name *Cutler* is applied to this coal bed because it is generally associated with the Cutler limestone.
3. The name *Galum* is applied to this limestone because it is well exposed along Galum Creek near Pinckneyville, Illinois.
4. See G. H. Cady, "Areal geology of Saline County," *Trans. Illinois Acad. Sci.*, Vol. 19 (1927), p. 261.
5. The name *Jamestown* is applied to this limestone because it is typically well exposed in the vicinity of Jamestown, Perry County, Illinois.
6. See Cady, *op. cit.*

stone is present in central Illinois 150–200 feet above the upper of a pair of limestones having a relationship similar to that of the Shoal Creek and Carlinville limestones of Kay and Lee (Fig. 3). This upper

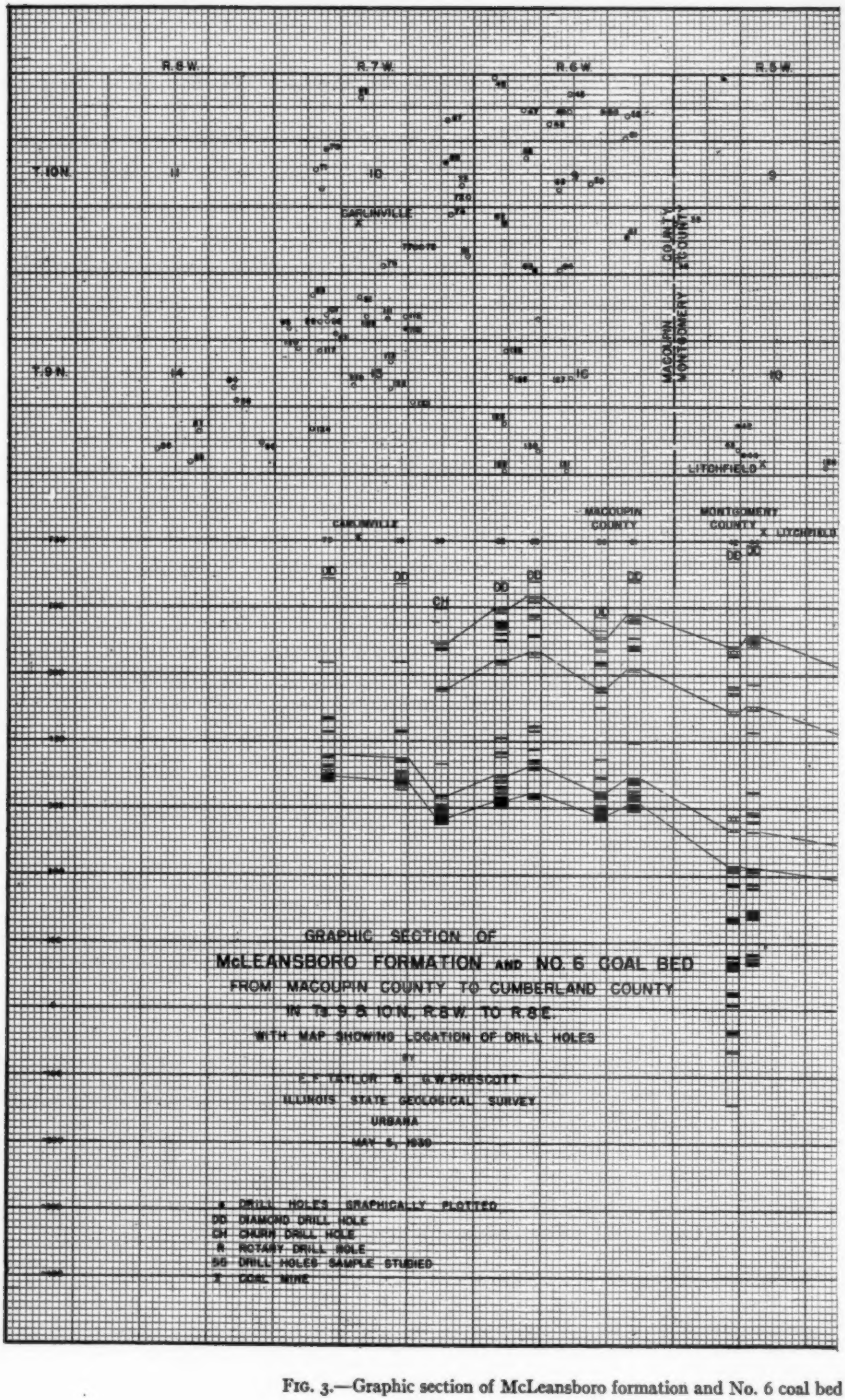

FIG. 3.—Graphic section of McLeansboro formation and No. 6 coal bed

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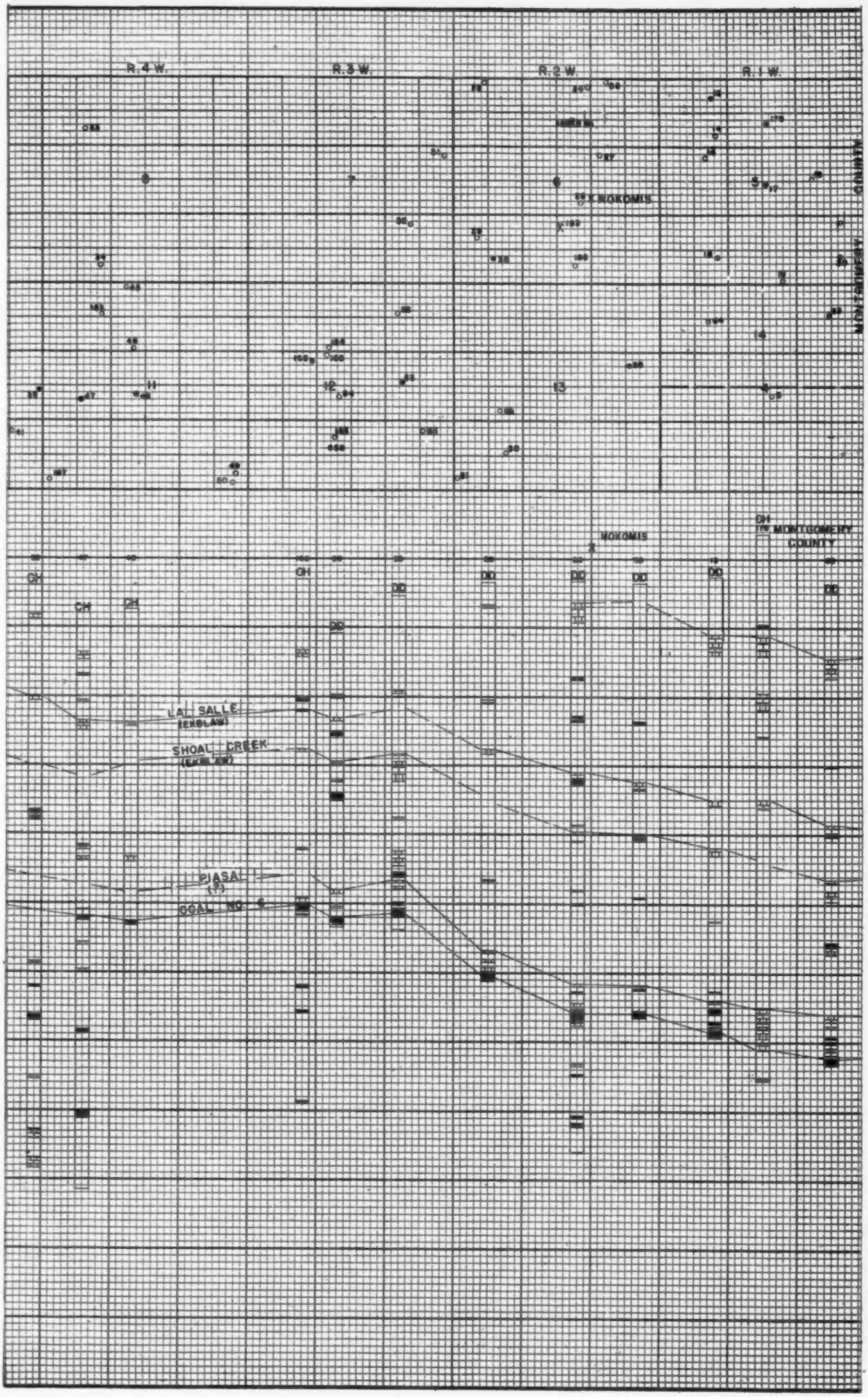


from Macoupin County to Cumberland County.

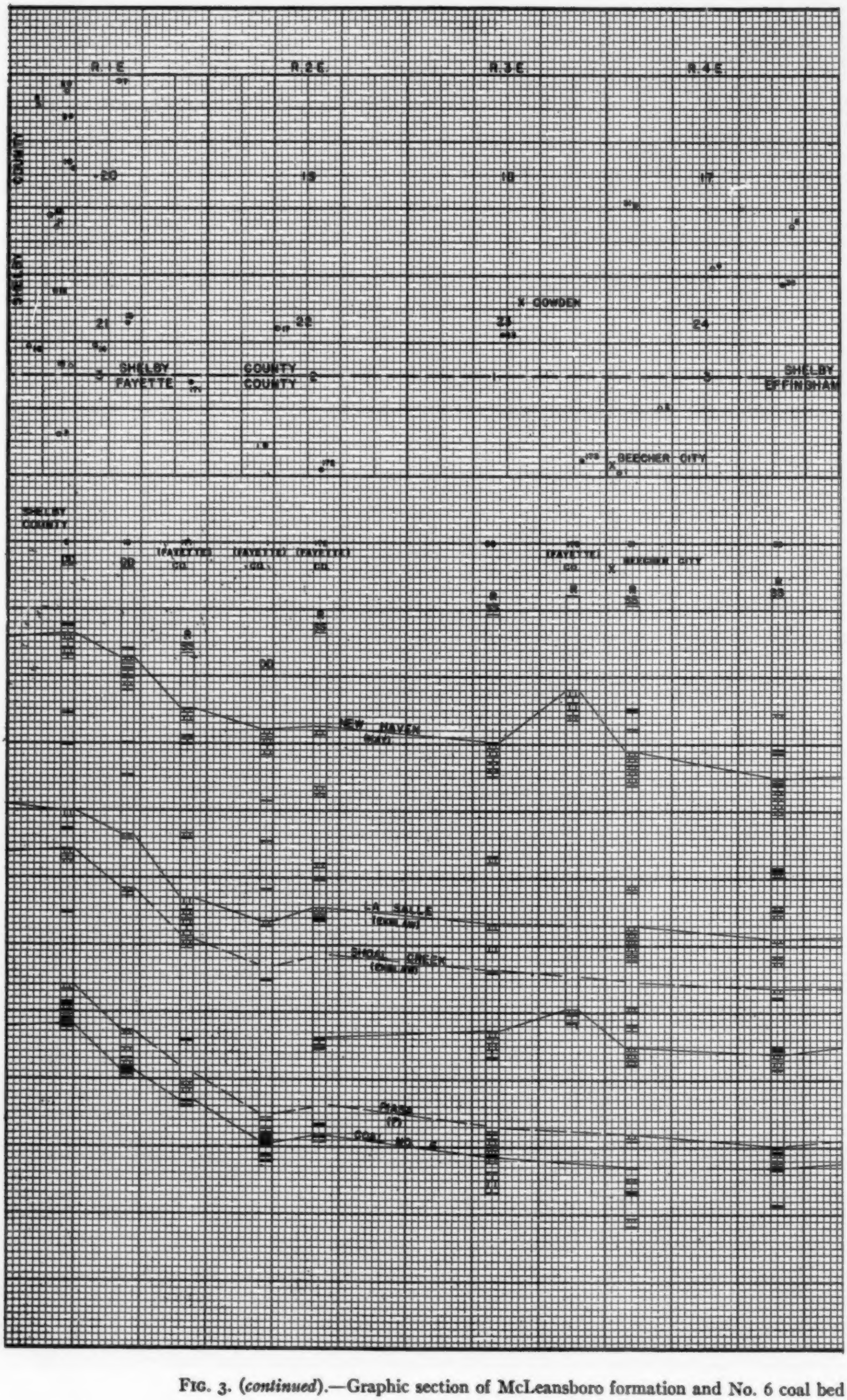
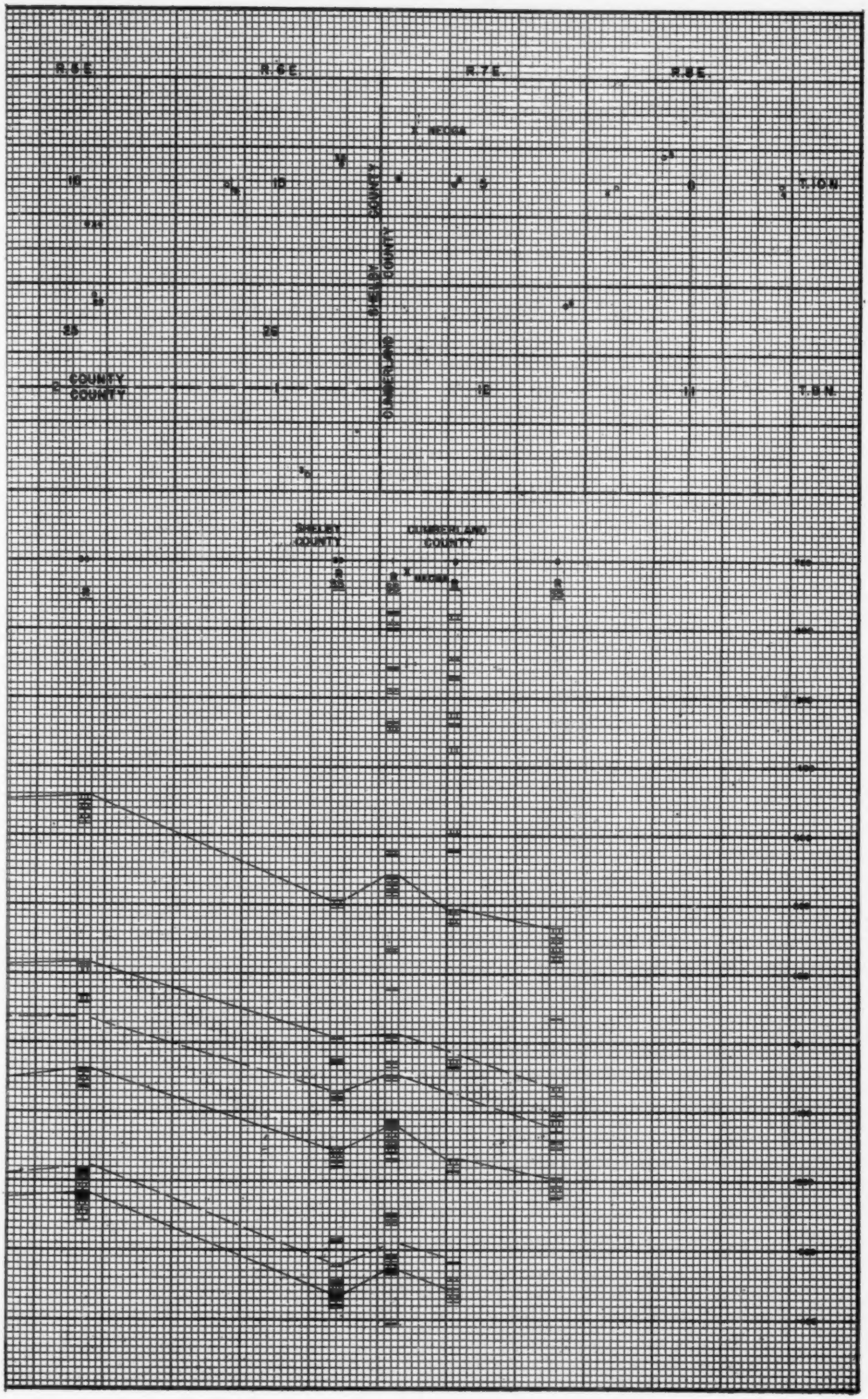


FIG. 3. (*continued*).—Graphic section of McLeansboro formation and No. 6 coal bed



from Macoupin County to Cumberland County.

limestone passes entirely beneath a section of the Pennsylvanian system in Cumberland and adjacent counties in which Newton and Weller[9] have identified certain beds as the LaSalle limestone, that is, equivalent to the Shoal Creek of Kay and Lee.

This upper New Haven limestone of Kay has a common thickness of 25–40 feet and is encountered in most drilling in the central counties of the state, as noted by Kay, and lies 500–600 feet above Herrin (No. 6) coal bed. This interval is about the same as that separating the limestone cropping out at New Haven from the Herrin coal but the continuity of this upper limestone in Cumberland and adjacent counties in the central part of the basin with the limestone at New Haven seems very doubtful. If the New Haven of Kay is younger than the limestone at New Haven, there is obviously an area in the central part of the state underlain by this upper limestone and a marginal line of outcrop which has not been traced. The graphic section prepared by Taylor and Prescott indicates that one position of such outcrop is in eastern Montgomery County, and it seems probable that an exposure of the limestone has recently been located near Millersville, Christian County, Illinois. No name has been proposed for this upper limestone other than New Haven, except that the geologists employed by some of the oil companies that have drilled in the central part of the basin commonly refer to it as the LaSalle, which adds further confusion to the nomenclature.

SHOAL CREEK-CARLINVILLE LIMESTONES CONTROVERSY

Probably no group of beds in the Pennsylvanian system in Illinois has received more severe treatment by stratigraphers than that group extending from the base of the Carlinville limestone of Lee and Kay to the top of their Shoal Creek limestone. There is no question about the presence of these two limestones since they may be observed in outcrop in what is essentially a continuous exposure in the vicinity of Carlinville, and limestones at the same position and having the same relationships have been penetrated in many drill holes and mine shafts. The confusion in nomenclature has come from the misinterpretation of exposures, isolated exposures apparently being difficult to identify. These difficulties seem to be in part due to the failure to make suitable allowance for regional dip such as is manifested by the structure of the underlying Herrin (No. 6) coal bed.

The attempt to trace these beds south and southeastward in drill records encounters difficulty first because of an apparently increasing

[9] William A. Newton, and J. Marvin Weller, "Stratigraphic Studies of the Pennsylvanian Outcrops in Part of Southeastern Illinois," *Illinois State Geol. Survey Rept. Investig.* 45 (1937), Pl. 1.

interval to Herrin coal bed, and secondly because the lower limestone, the Carlinville of Lee and Kay, becomes less persistent in that direction.

Additional difficulty in correlation has arisen apparently because of the indiscriminating use of the name Shoal Creek for what are apparently different limestones exposed in eastern Madison, western Clinton, southwest Bond and in Washington counties. The identification is made irrespective of the evident persistence of interval between the two limestones and Herrin (No. 6) coal bed, and a regional eastward dip of 6–8 feet per mile. Thus, a limestone outcrops along Shoal Creek which runs south in western Clinton County. A somewhat similar limestone also crops out along Sugar Creek which also flows south but about 7–8 miles west of Shoal Creek. According to Shaw and Udden[10] the altitude of Herrin coal bed declines about 75 feet from Sugar Creek to Shoal Creek. The exposures of the limestone being at about the same altitude, it seems probable that the limestone exposed along Shoal Creek is actually stratigraphically higher than that exposed along Sugar Creek and that the identification of the limestones on both creeks as Shoal Creek limestone is probably a mistake. Descriptions of the limestones such as are given by Jon A. Udden[11] indicate that the exposures are sufficiently different so that two limestones may well be represented.

In 1932 Sidney Ekblaw[12] reviewed the Shoal Creek-Carlinville problem under the supervision of H. E. Wanless and came to the conclusion that the limestone exposed along Shoal Creek, that is the easternmost limestone, is the same as the lower or Carlinville limestone at Carlinville as defined by Lee. Lee earlier correlated the Shoal Creek limestone with the upper limestone at Carlinville and called it the Shoal Creek. Both Lee and Ekblaw apparently regarded the basis for their correlations as more or less self-evident and produced little or no definite support for their conclusions. It may be pointed out that Lee states that the interval to the Herrin (No. 6) coal bed from his Shoal Creek limestone is 275–325 feet in the Gillespie-Mt. Olive quadrangles and 350 feet at Breese along Shoal Creek in Clinton County. If the limestone exposed at the Timmerman quarry 4 miles northeast of Breese, and here possibly 375 feet above the Herrin (No. 6) coal bed, is actually the lower limestone as believed by Ekblaw,

[10] E. W. Shaw and J. A. Udden, *op. cit.*

[11] Jon A. Udden, "Notes on the Shoal Creek limestone," *Illinois State Geol. Survey Bull. 8* (1907), pp. 117–26.

[12] Sidney E. Ekblaw, "The Question of the Shoal Creek and Carlinville Limestones," *Trans. Illinois Acad. Sci.*, Vol. 25, No. 4 (May, 1932), pp. 143–45.

then the upper limestone, that is Lee's Shoal Creek, would be more than 400 feet above coal No. 6. This is as much as 100 feet in excess of the maximum interval reported by Lee, and the evidence of drilling does not bear out the probability of such a divergence of beds in the distance involved. Indeed comparison of logs of wells drilled in eastern Clinton County indicates the persistence of two limestones having the stratigraphic position of the Carlinville and Shoal Creek limestones as they occur in Macoupin County at least as far east as Centralia. Here the lower limestone is about 300 feet and the upper limestone about 400 feet above the Herrin (No. 6) coal bed. The stratigraphic pattern seems to be essentially the same as that seen in the graphic section fron Macoupin to Cumberland counties prepared by Taylor and Prescott.

The upper or Shoal Creek limestone of Lee is not uncommonly underlain by a black fissile shale or "slate" beneath which there is commonly a thin bed of coal, nowhere more than a foot thick. No such coal horizon is reported by Lee to underlie the Carlinville limestone at the type locality or on the Gillespie or the Mt. Olive quadrangle. Ekblaw, on the other hand, describes a black sheety shale and coal bed a short distance below his Shoal Creek limestone (Carlinville of Lee) in his generalized section and reports no coal below his LaSalle limestone (Shoal Creek of Lee). These differences in interpretation and geological succession as reported by competent geologists are difficult for the economic geologist to comprehend and indicate that the solution of the controversy will require careful and discriminating observations with due consideration of the correlations made by both Lee and Ekblaw and of the structural conditions that exist.

The correlation of the upper or Shoal Creek limestone with the LaSalle limestone, that is the cement rock limestone at LaSalle, is based entirely on similarity in the stratigraphic pattern at LaSalle and at Carlinville so far as the writer is aware. In this case the stratigraphers have used the system of matching the grouping and spacing of beds to establish correlations, since there is no possibility of tracing the beds in exposures from one region to another. No particular objection exists to such a correlation so far as the present writer is concerned, so long as its basis is understood and the possibility of error realized. The very local distribution of the typical cement-rock limestone at LaSalle makes comparison on the basis of lithological similarity of little significance. A mile west of LaSalle the LaSalle limestone has little if any resemblance to the beds composing what would probably be called the typical LaSalle limestone.

The correlation of the Carlinville (Shoal Creek of Ekblaw) with

the New Haven is again largely based on the procedure of log matching. A limestone which may be either the Carlinville or the Shoal Creek of Lee is present in the shaft of the mine at Nashville, Washington County, about 400 feet above Herrin (No. 6) coal. There is only one such limestone reported and it is underlain by a thin coal bed. The interval is such as to suggest to the writer that this limestone is probably the upper or Shoal Creek limestone. The writer believes that Wanless, on the other hand, regards it as the Carlinville of Lee. So likewise the limestone cropping out at Radom, that near Galatia, and that at New Haven, except that in these latter two places the interval to the Herrin (No. 6) coal bed has increased to about 500 feet. Occasionally in drill holes in intervening positions in Jefferson, Franklin, and Saline counties two limestones having the general position of the Carlinville and Shoal Creek are reported. The uppermost of these limestones is between 400 and 500 feet above coal bed No. 6. There seems to be about as good evidence that the New Haven limestone represents the Shoal Creek of Lee as the Carlinville of Lee.

If the New Haven limestone represents Lee's upper limestone, called the Shoal Creek, it must be assumed that in many places between New Haven and western Clinton County the lower limestone is absent or poorly represented in the succession so that it commonly is not recorded in the logs. On the other hand correlating the New Haven with the Carlinville of Lee involves postulating a considerable thickening of the interval to the Herrin (No. 6) coal bed between the two localities. The basis for such belief rests very largely in the tenets of the cyclical theory of deposition which in general call for a widespread distribution of the individual members of each cycle.

These statements indicate some of the uncertainties that exist with respect to the correlation and identification of the Shoal Creek, LaSalle, Carlinville, and New Haven limestones in Illinois. The uncertainties become increasingly complex if Indiana limestones at the same general horizons are considered.

IDENTITY AND CORRELATION OF LONSDALE, PIASA, CUTLER, AND BANKSTON FORK LIMESTONES

This group of limestones lies between the Carlinville of Lee and the Herrin (No. 6) coal bed. Concerning their identity, continuity, and correlation there is much uncertainty in spite of the local distinction of each as a horizon marker. Limestones at this general horizon were not included in Kay's list of distinctive horizons. The graphic sections of Taylor and Prescott show a limestone at an intermediate position between the Carlinville of Lee and Herrin (No. 6) coal bed

which is usually associated with a variegated, usually a red, shale in logs of wells located in the central part of the basin. This limestone appears to give way toward the west in western Montgomery County and in Macoupin County, although the Piasa limestone is known to crop out in western Macoupin County.

Wanless[13] regards the Piasa as distinctly different and somewhat older than the Lonsdale limestone. The latter is a persistent bed of limestone in northern and western Illinois occurring in the interval separating coal bed No. 7 and a bed of limestone possibly the equivalent of the Carlinville or a closely adjacent limestone in the Longwall district of northern Illinois. Inasmuch as the Lonsdale and Piasa limestones never occur with their typical lithologic appearance in the same outcrop, although the exposure may cross the position of both horizons as defined by Wanless, and inasmuch as both limestones are undoubtedly nearly at the same stratigraphic position, although said to be in different cyclical formations, better evidence should be advanced than is now available before the existence of two limestones can be accepted as definitely established.

Both the Piasa and the Lonsdale limestones are characterized by the presence of a long slender form of fusulinoid fossil not found in lower limestones. In certain places these are found in great abundance, but this is not commonly the case.

The Cutler-Bankston Fork succession was first described by Bell, Ball, and McCabe in 1931.[14] It is a succession that can be observed in outcrop at numerous places between Belleville and Pinckneyville, but is less commonly fully exposed east of the DuQuoin anticline. Exposures of the Bankston Fork limestone are fairly common in Saline County, but the section above this limestone is rarely seen, and where seen the Cutler limestone if correctly identified does not have the distinctive lithological characteristics that it possesses west of DuQuoin, but rather closely resembles the Bankston Fork limestone. West of DuQuoin the two limestones are readily differentiated in exposures, but this is not so easily done in Williamson, Saline, and Gallatin counties. Their relation to associated coals is the best means of differentiation east of the DuQuoin anticline. What appear in graphic logs to be both limestones and the two thin coal beds that lie between them are commonly reported so that the continuity of these beds in southeastern Illinois seems probable.

[13] Harold R. Wanless, *op. cit.*

[14] A. H. Bell, C. G. Ball, and L. C. McCabe, "Geology of the Pinckneyville and Jamestown Areas, Perry County, Illinois," *Illinois State Geol. Survey, Illinois Petroleum 19* (April 11, 1931), p. 3.

The Anvil Rock sandstone intervenes between the Bankston Fork limestone and the cap rock of coal No. 6 in some places in southern Illinois, considerably increasing the interval between these two beds where such intervention occurs.

The correctness of the correlation of these two limestones of southern Illinois with the Piasa (Bankston Fork) and Lonsdale (Cutler) of central Illinois appears to the present writer to be very uncertain. Neither the Piasa nor the Lonsdale can be definitely traced from outcrop to outcrop at closely spaced intervals to definite agreement with the southern Illinois limestones. The corresponding limestones are different lithologically and associated sediments and stratigraphic relationships are different. According to Henbest[15] neither of the southern limestones contains the elongate form of fusulinoid fossil characteristic of the Piasa and Lonsdale limestones.

> Instead they are characterized by the presence of fat or ventricosely fusiform fusulinids formerly misnamed *Girtyina ventricosa*, now properly known as *Fusulina girtyi*, and an unpublished new species *Fusulina illinoisensis* Dunbar and Henbest (ms.).

If the Bankston Fork and Cutler limestones are not the equivalent of the Piasa and Lonsdale limestones it is probable that they underlie the latter limestones, although this assumption is as poorly founded as the assumption that they are the same, except for the fact that fossil contents are different and more nearly resemble the fossils of the Herrin limestone than those of the Piasa and Lonsdale limestones.

The present writer is inclined to place any limestone intervening between the Cutler limestone and the Carlinville limestone of Lee (Shoal Creek of Wanless), particularly a limestone associated with variegated shale, at the position of the Lonsdale (or Piasa) limestone. The occurrence of such a limestone in the graphic section prepared by Taylor and Prescott has been noted. It is noteworthy that Shaw and Udden suggested a possible correlation with the Lonsdale of a limestone 2–6 feet thick called the "top limestone" exposed in several places in the Belleville quadrangle. This limestone according to Shaw and Udden contains a long slender form of fusulinoid fossil "quite different from the form of Fusulina found in the roof limestone over the Herrin coal."[16]

In general, limestone at this position is not a distinctive part of the succession in southern Illinois, and its outcrops have scarcely ever been described. It is possible that its position is not far from that

[15] Lloyd G. Henbest, personal communication (June 14, 1939).

[16] E. W. Shaw and J. E. Udden, "Belleville-Breese, Illinois," *U. S. Geol. Survey Geol. Atlas Folio 195* (1915), p. 6.

of coal No. 8, a fairly persistent coal about midway between coal beds of the Carlinville-Shoal Creek group and those of the Cutler-Bankston Fork group.

The Lonsdale-Piasa, Cutler-Bankston Fork correlation is one of the most important uncertainties of the McLeansboro succession. Its solution undoubtedly involves important aspects of the cyclical theory of sedimentation. The settlement of the controversy will involve, first, a careful scrutiny of the field relationships of both the Piasa and Lonsdale limestones and the determination of their relative positions. It will then be necessary to work out the relative position of the Piasa-Lonsdale succession and the Cutler-Bankston Fork succession across Madison and St. Clair counties. It is not improbable that the outcrops may be adequate to establish the facts of the relationship in this area.

CONCLUSION

Some of the significant uncertainties in stratigraphic identity and correlation in the McLeansboro formation of the Pennsylvanian system in the Illinois basin have been discussed. These uncertainties exist in spite of the considerable amount of surface mapping and delineation of the subsurface structure of the Herrin (No. 6) coal bed that has been undertaken. The current generalizations in regard to the succession do not agree in important particulars, due in part to the paucity of exposures, making it difficult to compile a complete columnar succession from the outcrops, and in part to apparent miscorrelation of such exposed limestones as are occasionally seen which are difficult to differentiate lithologically, and in further part to an apparent failure to determine the extent of parallelism of the outcropping beds and the coal beds of which the structure has been delineated. The uncertainties involve the correlation and identification of the more important of the McLeansboro limestones and the interpretation of the sedimentary history of the basin, particularly the matter of the wedge thickening of the clastic beds toward the trough of the Illinois basin.

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GOLDSMITH FIELD, ECTOR COUNTY, TEXAS[1]

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ABSTRACT

The Goldsmith field is on the Central Basin platform near the middle of the West Texas producing district. The limits of the pool have not been fully defined although active drilling has been going on for nearly two years.

The Goldsmith structure is a very large, compound uplift which has grown by repeated movement during all geologic epochs since deposition of the producing formation.

The oil and gas reservoir is a widespread, porous zone 400 feet below the top of the main Permian dolomite. An enormous volume of free gas occupies the upper part of this reservoir and rests on the body of oil which is 60–100 feet thick and occurs at a nearly constant subsea depth throughout the pool. Sulphur water is below and in contact with the oil in most parts of the pool. Porosity of this reservoir is believed to have been developed by subaerial erosion and solution.

LOCATION

The Goldsmith field is in Ector County, Texas, near the center of the Permian basin of West Texas and southeastern New Mexico, and is one of the many pools situated on or near the eastern flank of the major structural feature known as the Central Basin platform. Figure 1 shows the geographical position of the Goldsmith field with respect to other pools of Ector County and the town of Odessa, 15 miles southeast.

The Goldsmith field is still in an active developmental stage. Its limits have not yet been defined at all points, although the major part of the ultimate producing area has probably now been outlined. On December 1, 1938, the field contained 588 producing wells, 3 gas wells, 14 drilling wells, and embraced a proved area of 16,000–17,000 acres.

HISTORY

No single wildcat can properly be designated as the discovery well of this large field. During the summer of 1930, the Penn Oil Company and the Devonian Oil Company drilled their Goodman No. 1 near the east line of Sec. 27, Blk. 44, T. 1 N. This test encountered a small amount of free oil, and was abandoned at total depth of 4,398 feet. It now appears that it was located about a mile east of the east edge of production in the Goldsmith field.

The Goldsmith area received no further testing for 4 years, although during that interval the North Cowden, Addis, and Harper

[1] Read before the Association at New Orleans, March 17, 1938. Manuscript received, June 20, 1939.

[2] Geologist, Landreth Production Corporation.

[3] Chairman, Goldsmith Pool Engineering Committee.

pools were discovered in other parts of Ector County. In February, 1934, C. J. Davidson and the Atlantic Refining Company's Cummins No. 1 was spudded in Sec. 10, Blk. 44, T. 1 N., 9 miles northwest of the old Penn-Devonian test. In May of the same year the Landreth Production Corporation's Scharbauer No. 1 (later Landreth-Humble's Scharbauer No. 1) was spudded in Sec. 20, Blk. 44, T. 1 N., 2 miles

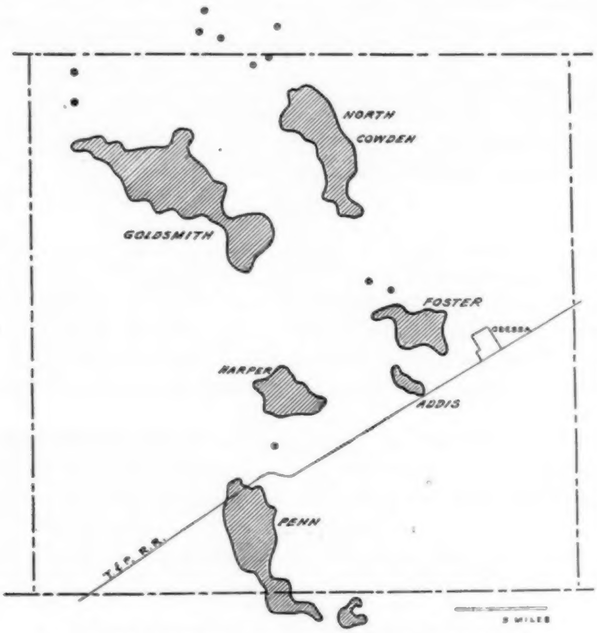

FIG. 1.—Map of Ector County, Texas, showing oil fields. Small circles are isolated producing wells. October, 1938.

west of the old Penn-Devonian test. The Davidson-Atlantic well was completed in August, 1934, producing about 30 barrels of oil per day and 8 million cubic feet of gas after shot and acid treatment. The Landreth-Humble well encountered oil which gauged 40 barrels per day natural and 25 million cubic feet of gas. The operators completed this test as a gas well in December, 1934.

In July, 1935, the Landreth Production Corporation completed their Scharbauer 1-A, Sec. 13, Blk. A, producing a small amount of oil and large volume of gas; and the Gulf Oil Company completed their Goldsmith No. 1, Sec. 10, Blk. 44, T. 1 S., producing 1,277

barrels per day. Following these completions the Gulf Oil Company and the Phillips Petroleum Company initiated a leisurely drilling campaign on their blocks at the south end of the Goldsmith area. By the beginning of 1937 several wells had established the presence of large-caliber production over the central part of the Goldsmith structure, and an intensive drilling campaign was in progress.

At the time of discovery of oil under the Goldsmith structure the large North Cowden pool had already been discovered and partly outlined. The latter was presumably a typical structure on the east rim of the Central Basin platform; therefore, the Goldsmith structure, several miles due west, was obviously an "inside fold." As such, it was under more than ordinary suspicion, because practically all the pools then known were located on the extreme edge of the platform.

STRATIGRAPHY[4]

The formations encountered in the Goldsmith field include Cretaceous, Triassic, and Permian strata. With the exception of some slight variations in the dolomite section, the subsurface formations in the Goldsmith area are essentially the same as those found in other pools on the east side of the Central Basin platform. Figure 2 is a generalized graphic log of a typical well at Goldsmith.

SURFACE FORMATION

A thin layer of Lower Cretaceous "Basement" sands occurs at the surface throughout the Goldsmith field as well as in most of Ector County. These sands are about 80 feet thick and lie unconformably on Triassic red shales. The uppermost several feet of this "Basement sand" has been altered to calcareous caliche.

TRIASSIC

Approximately 1,500 feet of the Dockum group is present in the Goldsmith area. The upper 1,000 feet consists entirely of red shale. Below this shale a coarse red water sand, known as the Santa Rosa, is found. The thickness of this sand is approximately 250 feet. Underlying the Santa Rosa is another red shale zone about 150 feet in thickness, which constitutes supposedly the base of the Triassic.

PERMIAN

The rest of the rock strata penetrated to date are Permian in age, and may be divided into four members, described briefly as follows in descending order.

[4] See discussion by DeFord at end of this article.

Red silt.—These highest Permian red beds are easily distinguished from the overlying Triassic red beds, as they are much finer grained than the Triassic sands, and coarser textured and much more consolidated than the Triassic shales. In the Goldsmith field this member is 100–150 feet thick.

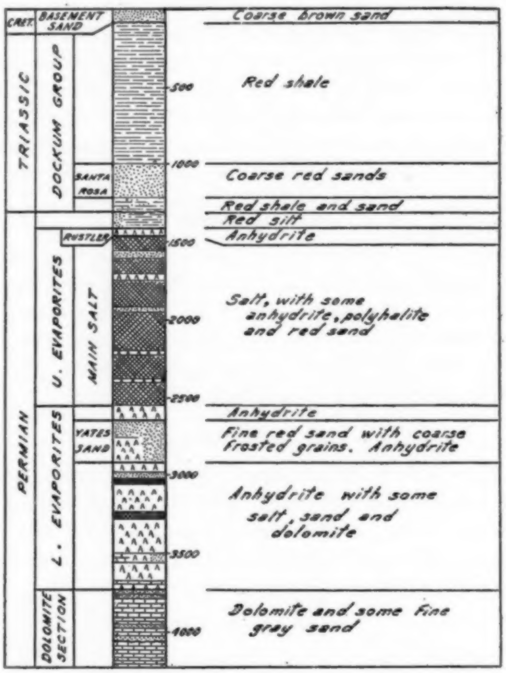

FIG. 2.—Generalized graphic log of formations encountered in Goldsmith field.

Upper evaporite.—This member which is 1,200–1,400 feet thick is composed essentially of salt. It also includes, however, a few beds of red sandstone and several thin beds of polyhalite and anhydrite. At the very top of the evaporite series is a 40-foot bed of anhydrite called the Rustler anhydrite.

Lower evaporite.—This member, 1,000 feet thick, consists mostly of anhydrite, but also contains some salt beds, a few thin beds of brown dolomite, and some red and gray sandstones. Near the top is

the widespread, prominent Yates sand, a fine-grained red sandstone characterized by included large, well rounded, frosted quartz grains.

Dolomite[5] *section.*—Lithologic details of this member of the Permian are indicated on the accompanying graphic log, Figure 3. Near the top is a sandy gray bed which is the most readily recognized

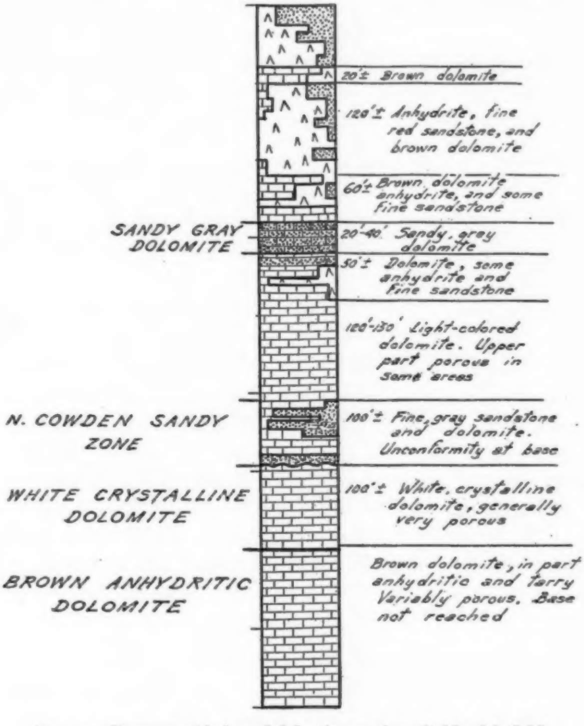

FIG. 3.—Type graphic log of dolomite section, Goldsmith field.

marker below the Yates sand. The lower part of the dolomite is the reservoir rock of the main accumulation of oil and gas.

[5] W. A. Cunningham states that the limestone of the West Texas Permian basin should be classified as a dolomite limestone. (W. A. Cunningham, "Dolomite in the Permian Limestones of West Texas," *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 19, No. 11 (November, 1935), p. 1686.) The writers have seen chemical analyses of cores taken from a single Goldsmith well, and these analyses showed the formation cored to be 80 per cent dolomite. This figure agrees closely with dolomite percentages found by Cunningham elsewhere in West Texas. In the same sense that Cunningham uses the term "dolomite limestone" to mean a limestone that is dominantly dolomite, the writers have chosen to use the single term "dolomite" throughout this paper.

OIL AND GAS ZONES

YATES SAND

Sweet gas is encountered in the Yates sand in some of the structurally high wells. The initial pressures are relatively high and several drilling wells have "blown out" from this zone. In several wells it has been necessary to set an intermediate string of casing through the sand.

The gas is not used, except for domestic purposes in the field camps.

"FOSTER" GAS ZONE

Approximately 100 feet below the top of the "Sandy Gray" dolomite, a porous oölitic dolomite about 50 feet thick contains volumes of gas up to 10 million cubic feet per day in the south part of the field. Traces of tar and dead oil have been noted in the cuttings; however, it is strictly a gas reservoir and is cased off.

This gas "pay" occupies the same stratigraphic position in the section as the first dolomite "pay" in the Foster pool. In both pools the dolomite is oölitic and overlain by a sandy section about 100 feet thick.

"NORTH COWDEN" SANDY ZONE

Approximately 250–300 feet below the top of the "Sandy Gray" dolomite, a sandy zone about 100 feet in thickness is found, which is correlated with the main producing sand zone in the North Cowden pool. In the Goldsmith field, the sands are tight and dolomitic. Minor showings of gas have been reported from this zone in a few cable-tool holes.

"GOLDSMITH" ZONE

The main producing zone in the Goldsmith field consists of an upper white crystalline dolomite and a lower brown anhydritic dolomite. At the contact of these two dolomites there is no break in continuity of the reservoir.

"White Crystalline" dolomite.—The "White Crystalline" dolomite is found approximately 400 feet below the top of the "Sandy Gray" dolomite, and immediately below the "North Cowden" sandy zone.

This white member is characterized by its white color and extreme crystallinity. Small amounts of crystalline anhydrite are found disseminated throughout parts of the member in bodies of various size, some of which are minute particles. Much of it appears to be secondary in origin. Stylolites are common; a few fossil casts are found. Oölitic zones are present in places and are either porous or

cemented by clear ice-like anhydrite and white dolomite. Secondary calcite has been found lining small cavity walls.

In the south and east parts of the field, porosity is found at or near the top of the "White Crystalline" dolomite and is continuous to and into the "Brown Anhydritic" dolomite. On the west side, a thin streak of porosity is encountered at the top of the white dolomite and is underlain by a wedge of impervious dolomite varying in thickness, but thickening to the west. Near the base of the white dolomite a rather consistent porous zone is found, which continues into the "Brown Anhydritic" dolomite. Some wells on the east side of the structure near the productive limits of the pool, show that in that direction the porous zone grades into a series of thin porous beds separated by impervious dolomite.

"Sugary" porosity is the common type in this zone; however, small cavities and channels have been found in cores. Microscopic examination of cores and cuttings shows that the sugary zones are made up of small dolomite crystals haphazardly arranged and poorly cemented. Porosity occurs between the crystals.

A "fusulinid" type of porosity also occurs in the white dolomite zone on the east side of the field. In this type the pores have the shape of large fusilines. However, no fossils are found, and the resemblance may be purely accidental.

The thickness of the "White Crystalline" dolomite varies throughout the field. It is definitely thinner in certain of the higher parts of the structure and thickens off structure, particularly toward the east.

"Brown Anhydritic" dolomite.—The white dolomite is underlain by the "Brown Anhydritic" dolomite. It is dark brown in color and fairly crystalline. Relatively large amounts of anhydrite, tar, sulphur, and some calcite are found in this zone.

Porosity in this "pay" is of a much poorer quality than that found in the white dolomite and porosity becomes poorer with depth. The quality of this porosity also varies areally, being best in the southern part of the field and poorest in the northern and northwestern parts of the field.

The thickness of the "Brown Anhydritic" dolomite is unknown, although as much as 400 feet has been penetrated in the Goldsmith area. Regional studies suggest that the contact of the "White Crystalline" and "Brown Anhydritic" dolomites is unconformable, although there is little supporting evidence within the immediate area of the field.

Permeability.—The difference in porosity and permeability of the two members of the producing zone is best indicated by differences in

performance of wells. Wells completed entirely in the "Brown Anhydritic" dolomite generally have daily potentials up to 1,000 barrels. Wells completed in the "White Crystalline" dolomite have potentials ranging up to 8,000 barrels per day. The higher productivity of the

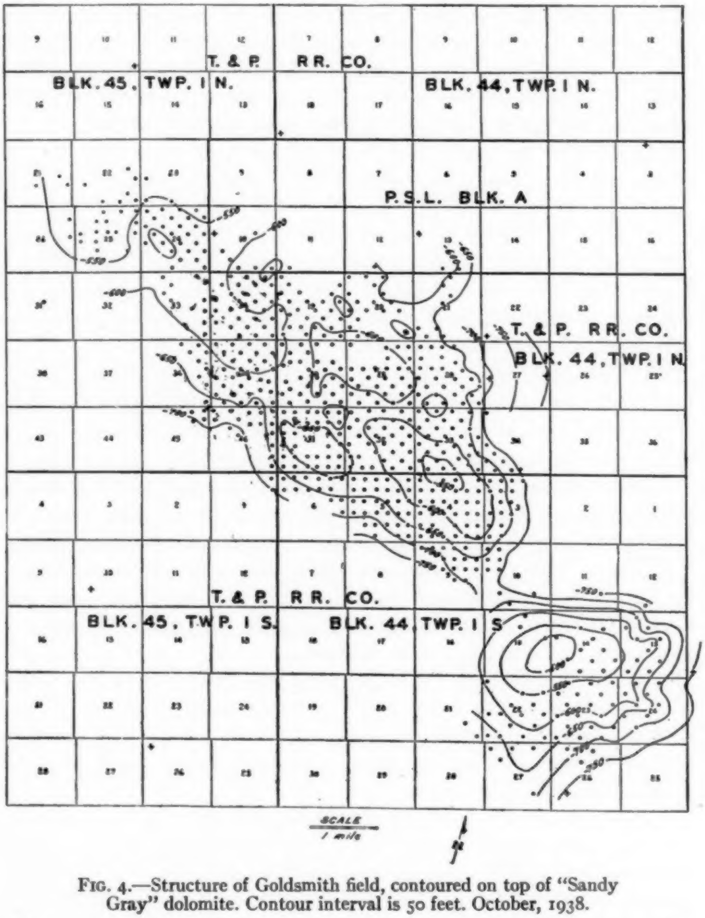

FIG. 4.—Structure of Goldsmith field, contoured on top of "Sandy Gray" dolomite. Contour interval is 50 feet. October, 1938.

white member is probably due to higher permeability rather than greater porosity. Cores and cuttings reveal that the pores in the "Brown Anhydritic" dolomite are of smaller size and to a great extent, in some wells, are filled with secondary anhydrite.

STRUCTURE

The structure map (Fig. 4) contoured on top of the "Sandy Gray" dolomite illustrates the subsurface structure of the Goldsmith field. The structural picture is incomplete at present (October, 1938) as the field remains undefined at several points.

The structure is in general flat-topped with the exception of a few local "highs" superimposed on the main structure. The dips are comparatively gentle. The west flank of the structure dips more gently than the east.

The edge of the structure is extremely irregular, particularly on the east side. Reëntrants and "noses" of varying size are common.

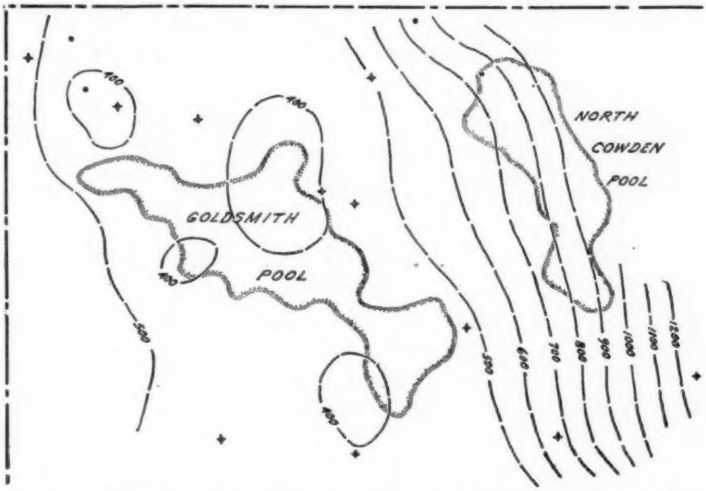

FIG. 5.—Northwestern Ector County, Texas. Contours show thickness of interval from top of "Sandy Gray" dolomite to top of "Brown Anhydritic" dolomite.

Some of the noses and some larger features such as the "South dome" suggest cross-folding at right angles to the main axis extending northwest and southeast.

STRUCTURAL HISTORY

For the purpose of unraveling the successive steps in the development of the present Goldsmith structure the writers have drawn a series of three isopach maps and one structure map (Figs. 5–8, inclusive). The assumption behind the interpretation of these isopach maps is that areas of thinner deposition were relatively uplifted and areas of thicker deposition were relatively depressed during the time

interval indicated. This series of maps shows that the Goldsmith region was subjected to earth movements during all periods of time from the epoch of the oldest beds penetrated down nearly to the

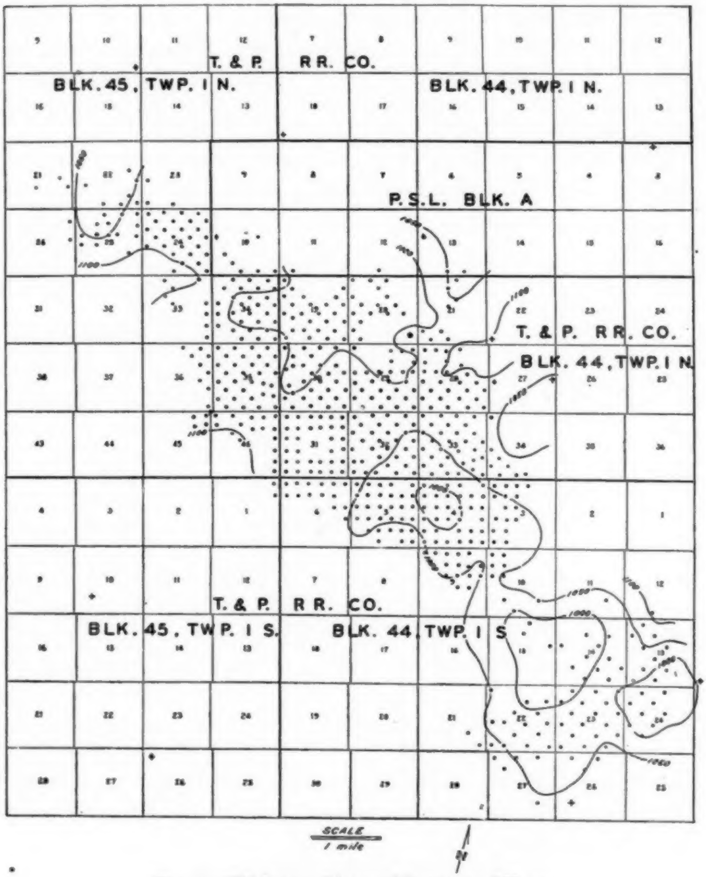

FIG. 6.—Thickness of interval from top of Yates sand to top of "Sandy Gray" dolomite.

present day. However, the intensity and locus of movement were different in each successive time interval.

Figure 5, covering the interval from the "Sandy Gray" to the "Brown Anhydritic," indicates the topography of the Permian dolomite of northwestern Ector County at the time of deposition of the

beds which are now the reservoir of the Goldsmith field. The Goldsmith area was a large elevated mass flanked on the west by a shallow depression, and on the east by a deep basin. The writers interpret

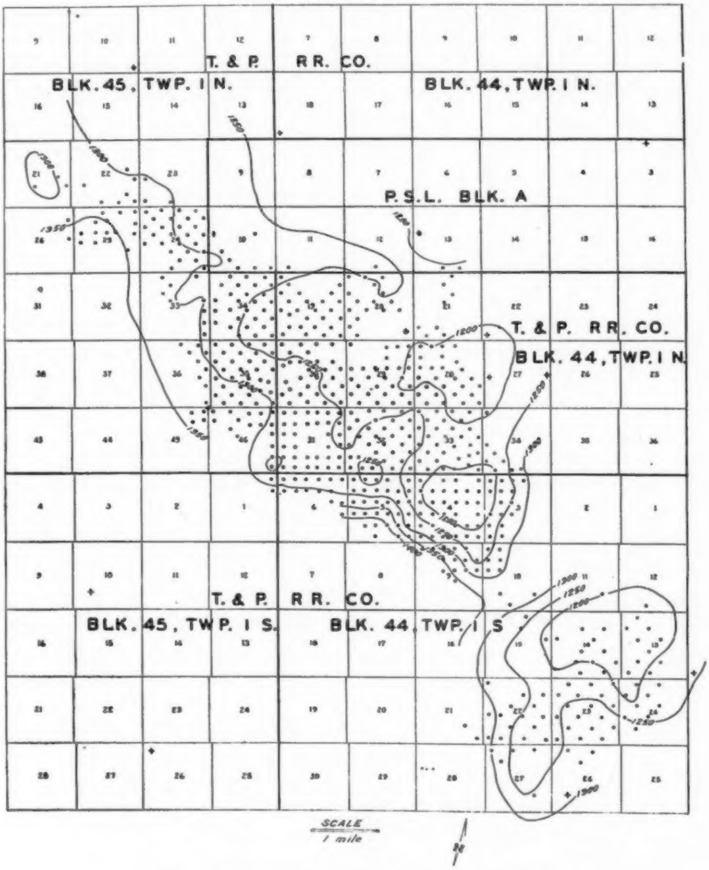

FIG. 7.—Thickness of interval from top of Rustler anhydrite to top of Yates sand.

this ancestral Goldsmith "high" as a large dolomite bank (a term preferred to the more limited word "reef") facing a marine deep on the east. That this bank was in part of depositional origin is suggested by the fact that marked lithologic changes occur within the "Brown

Anhydritic" dolomite down the east flank of the high as compared with its facies on top. Downdip this formation becomes much more shaley and much less dolomitic.

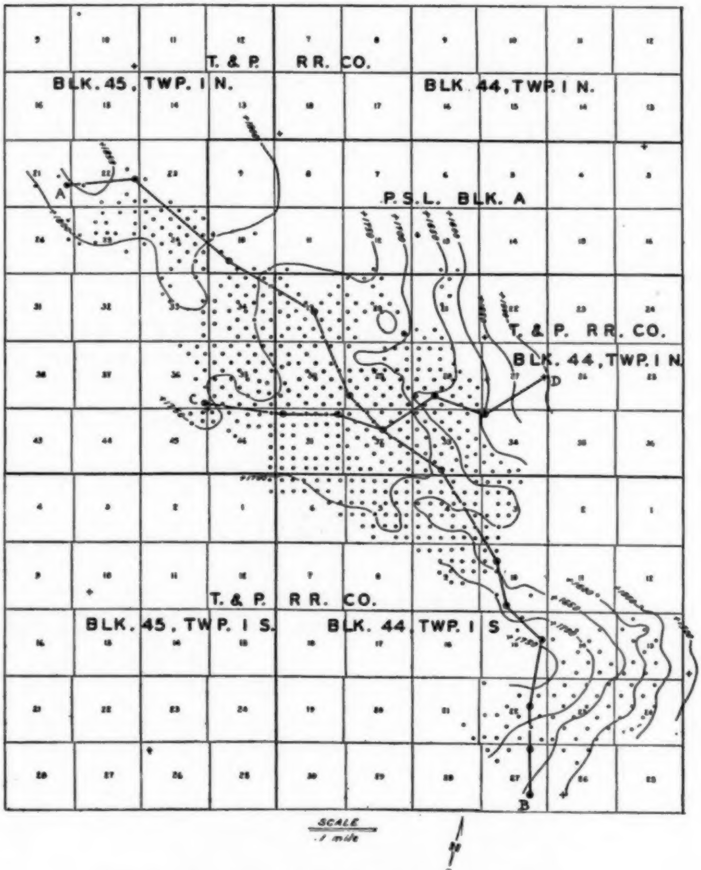

FIG. 8.—Structure of Goldsmith field contoured on top of Rustler anhydrite. Contour interval is 50 feet.

During the succeeding period, when beds from the "Sandy Gray" dolomite to the top of the Yates sand were deposited (Fig. 6), the earth's crust in the Goldsmith area was relatively quiescent, as the maximum relief developed at this time was only about 100 feet. It

is interesting to note that areas now well down on the east flank of the structure were then among the highest parts of the structure.

The next epoch, from the top of the Yates sand to the top of the Rustler (Fig. 7) is largely the time of deposition of the main salt body. This was probably much the shortest of any of the periods of time represented in this series of maps. However, it was a time of considerable crustal activity as a relief of more than 200 feet was developed. As in the preceding period, the loci of greatest uplift were well over on the flanks of the present structure. During this salt epoch there was developed the deep saddle which lies between the main body of the Goldsmith structure and the smaller dome at its south end.

There are not enough data to draw isopach maps on periods of time from the Rustler formation to the present day. However, approximately the same information is given by Figure 8, a structure map of the top of the Rustler. The structure shown by this marker is the sum of at least two distinct earth movements: an uplift of 250 feet or more in post Santa Rosa-pre-Cretaceous time, and a broad regional tilting, probably Tertiary in age, which caused the beds at the surface to rise toward the west at a rate of 15–20 feet per mile. The earlier post-Santa Rosa uplift produced a broad top, a steep east flank. Its axis of uplift was distinctly west of the axes of preceding uplifts.

To sum up the history of the Goldsmith structure: the structure as found to-day and as drawn on the "Sandy Gray" dolomite is the result of a succession of crustal movements each of which showed individual differences of magnitude and focus, but all of which were over the site of an older dolomite bank which was in existence before the reservoir rocks of the field were deposited.

RELATION OF ACCUMULATION TO STRATIGRAPHY AND STRUCTURE

The Goldsmith field produces from a common reservoir of the two-phase type. Gas, oil, and water are found at nearly constant subsea levels. Free gas is found above a subsea datum of −970 to −980 feet in the main part of the pool. The gas-oil contact in the "South dome" is approximately −980 to −990 feet. Figure 9 depicts by contours the thickness of the free-gas zone. It also indicates the individual gas caps. The size and location of the gas caps are determined not only by structure but also by the position of highest porosity within the "White Crystalline" dolomite.

In the gas-cap areas a gradational zone of distillate is present between the free gas and the oil. The manner in which gas and oil occur within the reservoir is shown in Figures 10 and 11.

The oil rests on sulphurous salt water. The oil-water contact varies

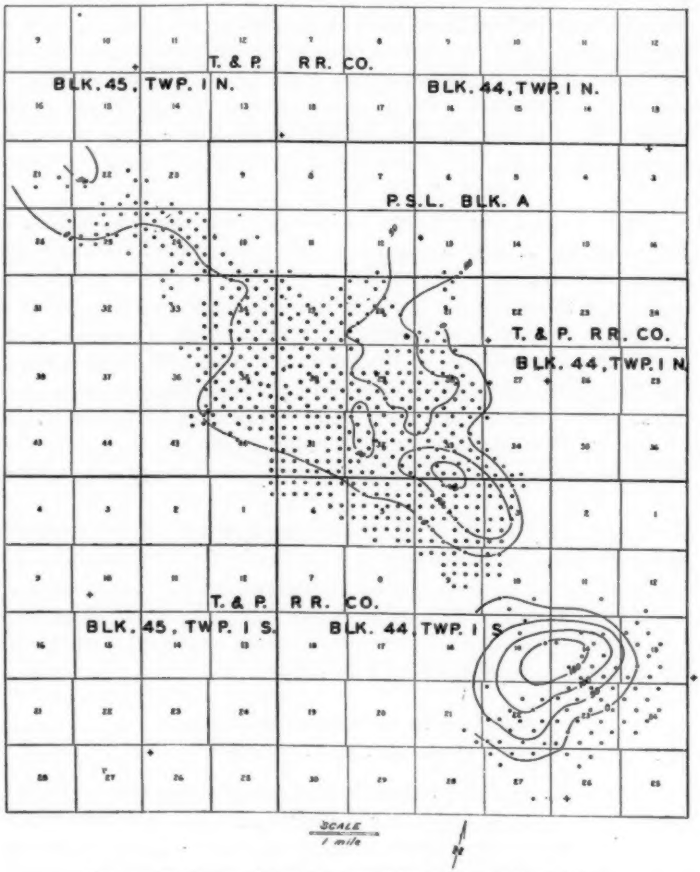

FIG. 9.—Thickness of free gas caps. Contour interval is 50 feet.

from a subsea depth of −1,013 to approximately −1,100 feet. Water has been found in both the "White Crystalline" and "Brown Anhydritic" dolomites. Figure 12 shows by contours the probable bottom-water level in the pool. It appears probable that fluid adjustment of

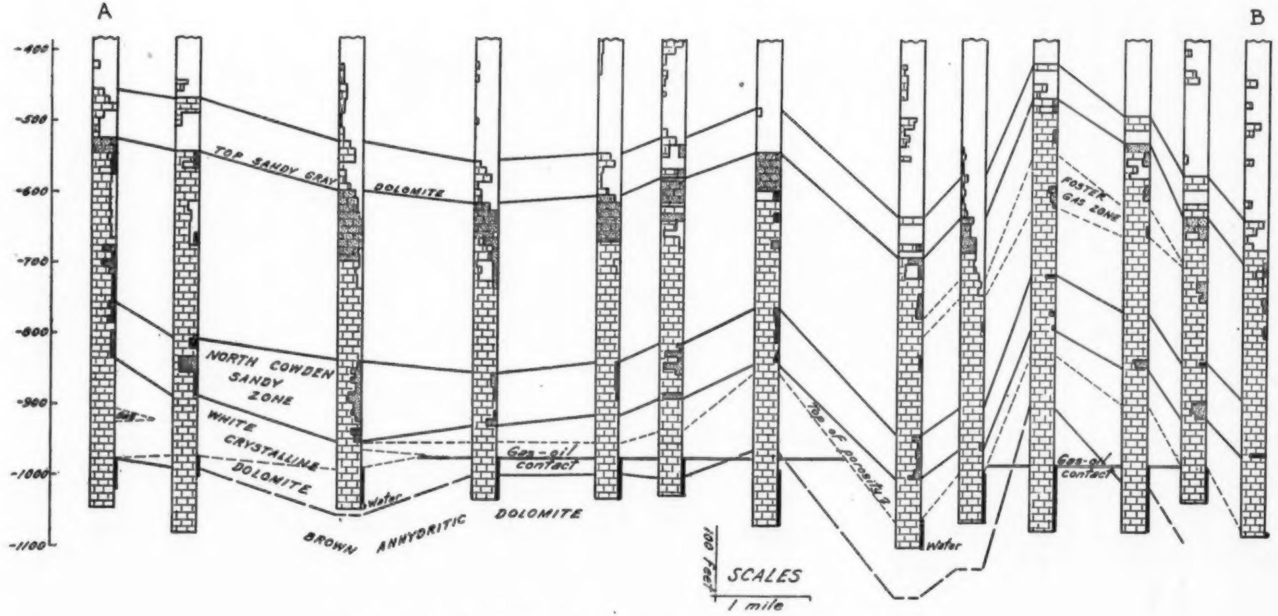

FIG. 10.—Northwest-southeast cross section, Goldsmith field (*AB* on Fig. 8).

the water and oil has not been uniform because of poor porosity and permeability in the "Brown Anhydritic" dolomite.

Bottom-hole pressure data obtained to date indicate that only in the "South dome" is there any effective pressure maintenance due to water drive. The other portions of the field are at present producing under volumetric control. However, where porosity and permeability will permit, it is probable that with declining field pressures a water

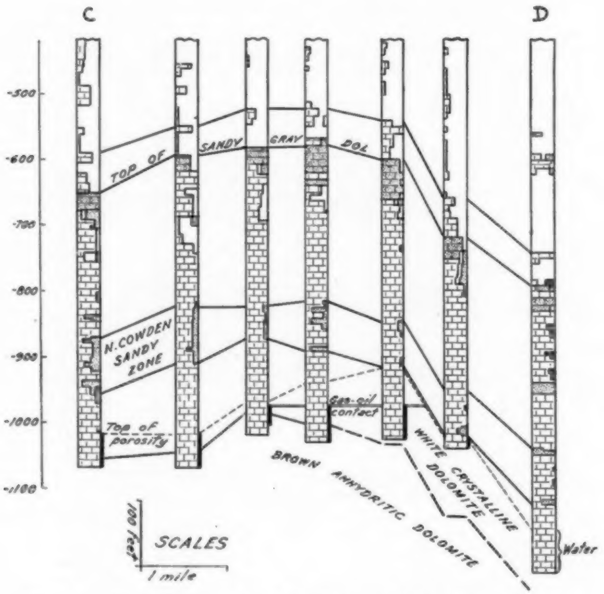

FIG. 11.—West-east cross section, Goldsmith field (*CD* on Fig. 8).

drive will become effective in areas now under volumetric control.

Fluid levels appear to be gradually changing since discovery. There is some evidence that the gas caps are expanding and the bottom-water level is moving upward.

REGIONAL RELATIONS

The Goldsmith field is one of a cluster of producing areas which are grouped within rather short distances of one another in Ector County. Measured between closest producers, the Goldsmith field is $3\frac{1}{2}$ miles from the North Cowden pool, and about 6 miles from both the Foster and Harper pools.

This group of pools exhibits several interesting similarities in stratigraphy, structure, and details of oil and gas accumulation. The producing zone at Goldsmith is stratigraphically about the same as the producing zones of both the Harper and Penn pools. The upper gas zone which occurs only over the south end of Goldsmith is correlated with part of the pay section of the Foster pool. The equivalents of the main producing zones of North Cowden contain at Goldsmith only small showings of gas.

The major axis of the Goldsmith structure has about the same northwest-southeast alignment as the axes of those other Ector County pools whose structures are well defined at present, that is, Penn, Addis, and North Cowden. However, the east-west trend of the local dome at the south end of Goldsmith has no counterpart elsewhere in the area. In actual height, the top of the main dolomite at Goldsmith is higher than any other part of Ector County except Penn pool which is 300 feet still higher.

As limited by its gas-oil and oil-water contacts, the body of oil at Goldsmith has a more definite position with respect to sea-level than oil accumulations of the other pools in Ector County. However, roughly, the subsea depth of oil at Goldsmith is the same as the higher part of the oil accumulations at North Cowden, Foster, and Addis pools. In the Harper pool, oil occurs at least 50 feet higher than at Goldsmith, and oil at Penn pool is at least 350 feet higher than at Goldsmith.

The Goldsmith reservoir is similar to the North Cowden and Addis reservoirs in that all three have free-gas caps immediately overlying the oil body. The gas-oil contacts at North Cowden and Addis pools can not be defined as closely as at Goldsmith, nevertheless in both pools the contact is at about 1,000 feet below sea-level, or very nearly the same as at Goldsmith. A little free gas occurs in the Foster pool in a few of the structurally highest wells at about 1,000 feet below sea-level. There is no free gas in the Harper and Penn pools.

ORIGIN OF POROSITY

The origin of porosity in limestone reservoirs has been explained by various theories, principally (1) solution associated with unconformities, (2) dolomitization, and (3) original porosity, including porosity occurring with reef growth.

With regard to the origin of porosity in the Goldsmith reservoir, the following facts are pertinent.

1. The reservoir rocks are overlain by sands or sandy dolomites which constitute a marked change in sedimentation over the nearly pure dolomites below the contact.

2. The dolomite of the pay zone is exceptionally crystalline.
3. Fossils are practically absent.
4. Porosity is encountered at the top or a few feet into the "White Crystalline" dolomite.
5. Porosity becomes poorer with depth and ultimately disappears.
6. Porosity is poorer on the west flank and parts of the east flank.
7. Pore spaces vary in size from capillary openings to small cavities and channels.
8. The areal and vertical distribution of porosity conforms more closely to the earlier attitude of the reservoir rock, as indicated by isopach maps, than it does to the present structure.

The writers believe that most of the facts here cited favor the theory that porosity at Goldsmith was developed by subaerial erosion and solution during a break in deposition now marked by an unconformity.

The presence of sand overlying the reservoir rocks marks a definite sedimentary break. (In fact, practically every dolomitic limestone reservoir in the Permian basin is overlain by a sand or sandy section.) It therefore seems logical to place an unconformity at the top of the "White Crystalline" dolomite.

Irregularities in both the horizontal and vertical distribution of porosity, as shown in a generalized way on the cross sections, indicate that development of porosity at Goldsmith can not be completely explained as due to a single simple period of subaerial exposure of a dolomite mass of uniform composition. The most widespread porous sub-zone is not at the top of the "White Crystalline" dolomite but at its base, and in the top of the subjacent "Brown Anhydritic" member. Throughout most of the west side of the pool, the "White Crystalline" dolomite above this porous sub-zone is largely impervious. The absence of porosity in parts of the reservoir rock which are elsewhere porous may be due to relatively greater insolubility (including less jointing and fracturing) and is probably due in part to the fact that some portions of the dolomite, although now structurally high, were not above water at the time that equivalent beds were undergoing subaerial leaching. In addition, before the deposition of the "North Cowden" sandy zone, the history of the Goldsmith dolomite mass was probably a complex succession of small downward and upward movements of the emergent dolomite, hence of fluctuating water tables; and even brief periods of complete submergence with renewed sedimentation—in short, a series of geologically short-lived events which have left no record other than apparent vagaries in distribution of porosity within the reservoir strata.

DRILLING AND PRODUCTION PRACTICES

Drilling practice.—Cable-tool, rotary, or a combination of both methods of drilling wells have been used in developing the field. However, the rotary method is used to a greater extent than cable tools.

The only addition to conventional rotary practice is the use of "pressure" drilling methods in the pay zones below the oil string, oil being used as the circulating medium. No trouble is encountered with rotary tools except an occasional blow-out from the small volumes of gas at fairly high pressures in the Yates sand on some high structural wells; consequently, there is no drilling-mud problem.

Accurate records of drilling time per foot are usually kept while drilling the pay zone. This information, along with examination of the rotary samples, furnishes valuable information on the porous and nonporous sections of the pay zone.

A few operators core the entire pay section from the oil-string casing seat to the total depth for lithologic and pay information.

Cable tools are used extensively to drill into the pay zone in the areas of low pressure and low permeability. One operator standardizes on top of the salt after setting and cementing an intermediate string of casing at this point.

Casing.—Two or three strings of casing are usually run and cemented, the prevailing program being the use of a surface and an oil string.

Surface casing ranging from 13-inch to 8⅝-inch outside diameter is run and cemented through the surface sands at various depths between 200 and 400 feet.

Oil strings ranging from 5½-inch to 7-inch outside diameter are run and cemented in the solid limestone section above the pay zone at depths ranging from 3,750 to 4,200 feet.

In the gas-cap areas of the field an effort is made to set the oil string at or below the gas-oil contact. The gas-oil contact is located by setting the oil string at a subsea depth where the gas-oil contact has been found in the particular area, by noting the gas-oil contact by means of saturation in cores or samples, by the use of drill-stem tests, and by the use of bottom-hole temperature surveys.

The penetration into the pay section can be safely determined from bottom-water table maps (Fig. 12). A sufficient number of wells have been drilled into the bottom-water zone to give good control in the field.

All wells are tubed as close to total depth as possible with either 2-inch or 2½-inch tubing.

Acidizing and shooting.—After reaching total depth all wells are either acidized or shot, or both, to increase well potentials, the choice of the methods used depending on the operator and the area. Acidizing

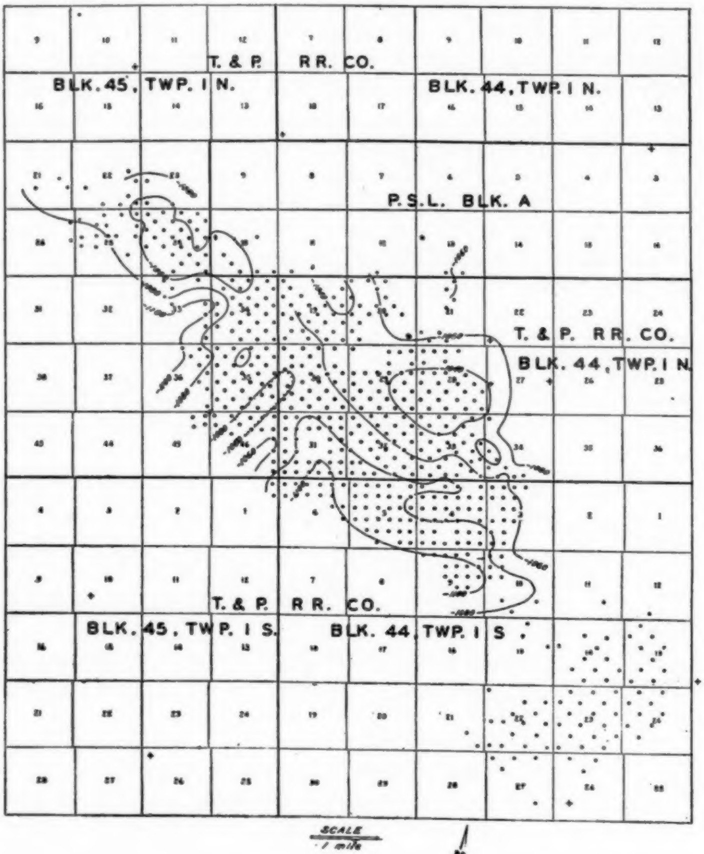

FIG. 12.—Map showing attitude of bottom water by contours drawn on bottom-water table. Contour interval is 20 feet. October, 1938.

is preferred by the majority of the operators as the cheaper method and one that leaves the bore hole in condition for future corrective work. The industry is familiar with the difficulties encountered in trying to reduce high gas-oil ratios or shutting off bottom water in a limestone shot hole.

Two methods of acidizing are used to confine acid to the lower oil-bearing parts of the pay section during treatment so that acid will not penetrate the upper gaseous portions of the "pay" and increase the gas-oil ratio: the two-pump method and the "floating" of acid into the well. In the two-pump method the tubing is run and set a few feet above the bottom of the hole and oil is pumped down the annular space while acid is being pumped down the tubing, the oil being pumped at a rate high enough to confine the acid to the lower part of the pay section. "Floating" in acid is a process in which acid is pumped down the tubing with a very low tubing pressure, and at such rate that the tubing pressure will not exceed the original tubing pressure, the object being to "syphon" the acid into the lower portion of the pay zone.

The conventional methods of shooting with nitroglycerine are used in the field, and an attempt is made to confine the shot to the porous parts of the pay zone rather than to shoot the entire open-hole section below the oil string.

Analysis of oil.—Table I shows an analysis of oil in the Goldsmith field made by the United States Bureau of Mines.

TABLE I

Analysis of Typical Sample of Crude from Goldsmith Field

GENERAL CHARACTERISTICS

Specific gravity, 0.854 — A.P.I. gravity, 34.2°
Per cent sulphur, 1.90 — Color, dark green
Saybolt Universal viscosity at 77°F., 54 seconds
Saybolt Universal viscosity at 100°F., 46 seconds

DISTILLATION, BUREAU OF MINES HEMPEL METHOD

Dry distillation — Varometer 745 mm. — First drop: 34°C. (93°F.)

Temperature C.	*Per Cent Cut*	*Sum Per Cent*	*Sp. Gr. of Cut*	*Degrees A.P.I. of Cut*	*Viscosity at 100°F.*	*Cloud Test Degrees F.*	*Temperature Degrees F.*
Up to 50							Up to 122
50– 75							122–167
75–100	4.5	4.5	0.691	73.3			167–212
100–125	6.0	10.5	.734	61.3			212–257
125–150	6.7	17.2	.758	55.2			257–302
150–175	6.9	24.1	.780	49.9			302–347
175–200	2.9	27.0	.794	46.7			347–392
200–225	5.5	32.5	.809	43.4			392–437
225–250	5.7	38.2	.821	40.9			437–482
250–275	7.5	45.7	.835	38.0			482–572
Vacuum distillation at 40 mm.							
Up to 200	3.1	3.1	0.851	34.8	40	10	Up to 392
200–225	6.1	9.2	.860	33.0	46	30	392–437
225–250	5.5	14.7	.872	30.8	58	45	437–482
250–275	5.2	19.9	.884	28.6	85	60	482–527
275–300	7.2	27.1	.895	26.6	150	75	527–572

Carbon residue of residuum 9.9 per cent. — Carbon residue of crude 2.5 per cent.

APPROXIMATE SUMMARY

	Per Cent	*Sp. Gr.*	*Degrees A.P.I.*	*Viscosity*
Light gasoline	4.5	0.691	73.3	
Total gasoline and naphtha	27.0	.751	56.9	
Kerosene distillate	11.2	.815	42.1	
Gas oil	15.6	.846	35.8	
Nonviscous lubricating distillate	10.6	0.864–0.886	32.3–28.2	50–100
Medium lubricating distillate	8.4	.886– .901	28.2–25.6	100–200
Viscous lubricating distillate	—	—	—	Above 200
Residuum	25.0	.961	15.7	
Distillation loss	2.2	—	—	

E. L. Garton
Sept. 3, 1937

Gas.—Table II is an average gas analysis of five gas wells located in various parts of the field. The gasoline content of the gas ranges from ½ gallon per 1,000 cubic feet to 3 gallons per 1,000 cubic feet, depending on the gas-oil ratio, separator pressure and the temperature under which the sample is taken.

TABLE II

AVERAGE ANALYSIS OF GAS FROM GULF'S GOLDSMITH NO. 11, SE. ¼, SEC. 27, BLK. 44, T.1 S., GULF'S GOLDSMITH NO. 21, NW. ¼, SEC. 3, BLK. 44, T.1 S., LANDRETH'S CUMMINS NO. B-2, SE. ¼, SEC. 24, BLK. 45, T.1 N., LANDRETH'S SCHARBAUER NO. D-1, NW. ¼, SEC. 32, BLK. 44, T.1 N., LANDRETH'S SCHARBAUER NO. K-1, SW. ¼, SEC. 34, BLK. 44, T.1 N.

	Per Cent
Methane	58.79
Ethane	18.09
Propane	13.84
Iso-butane	1.10
N. butane	4.63
Iso-pentane	0.60
N. pentane	1.10
Hexanes	1.85
Total	100.00

Considerable effort is made to drill and produce the wells in such a manner that the maximum amount of free-gas energy is saved in the field. In event the oil string has been set too high, or the well acidized with resulting high gas-oil ratio, the practice has been either to set a formation packer below the free-gas zone with a Fibrotex-Aquagel fluid seal above the packer, or squeeze off the gas zone with cement, or set and cement a liner below the free-gas zone.

It has been found that approximately 800 cubic feet of gas is found in solution per barrel of oil at reservoir pressures of 1,500 pounds. A gas-oil ratio in excess of 800 cubic feet per barrel indicates that free gas is being produced from the formation.

The weighted average field gas-oil ratio has been reduced by corrective work and improved completion practices since the discovery of the field, data as follows.

Survey	*Number of Wells*	*Gas-Oil Ratio (Cu. Ft. per Bbl.)*
April, 1937	69	5,638
August, 1937	186	4,491
Nov.–Dec., 1937	331	2,400
April, 1938	430	2,202
July–Sept., 1938	526	1,628

A gas displacement factor of 5,000 cubic feet per barrel is in effect in the field. A well producing in excess of 5,000 cubic feet per barrel will have its allowable reduced in proportion to a fraction of 5,000 cubic feet divided by the actual producing gas-oil ratio. This gas limit per well for the field stimulates remedial work in event a well is completed with a high gas-oil ratio, since the daily allowable of the well is reduced with increased gas-oil ratios.

Waters.—Table III shows typical analyses of surface water, Triassic water, and the bottom or edge waters encountered to date in the field.

TABLE III

SURFACE WATER

SAMPLE OF WATER FROM LANDRETH CAMP WATER WELL, SW. ¼, SEC. 28, BLK. 44, T.1 N.

	P.P.M.	*Reacting Values Per Cent*
Na	87.9	15.85
Ca	114.0	23.73
Mg	29.9	10.42
SO_4	340.0	29.60
Cl	55.0	6.25
HCO_3	100.8	14.15
SiO_2	26.8	
Total P.P.M.	754.4	100.00

SANTA ROSA WATER

SAMPLE OF WATER FROM 1,030-FOOT WATER WELL ON AMERICAN-MARACAIBO'S SCHARBAUER LEASE, SW. ¼, SEC. 19, BLK. 44, T. 1 N.

	P.P.M.	*Reacting Values Per Cent*
Na	1,138.7	46.22
Ca	42.8	1.89
Mg	22.6	1.89
SO_4	1,204.8	23.40
Cl	725.0	19.10
HCO_3	237.6	7.50
SiO_2	14.0	
Total P.P.M.	3,385.5	100.00

BOTTOM-HOLE WATER

SAMPLE OF WATER FROM 4,233–4,235 FEET FROM LANDRETH CUMMINS NO. 1A, SW. ¼, SEC. 10, BLK. A, P.S.L.

	P.P.M.	*Reacting Values Per Cent*
Na	32,110.2	43.72
Ca	2,698.9	4.24
Mg	788.9	2.04
SO_4	4,046.6	2.64
Cl	52.900.0	46.73
HCO_3	597.6	0.63
SiO_2	32.0	
Total P.P.M.	93,174.1	100.00

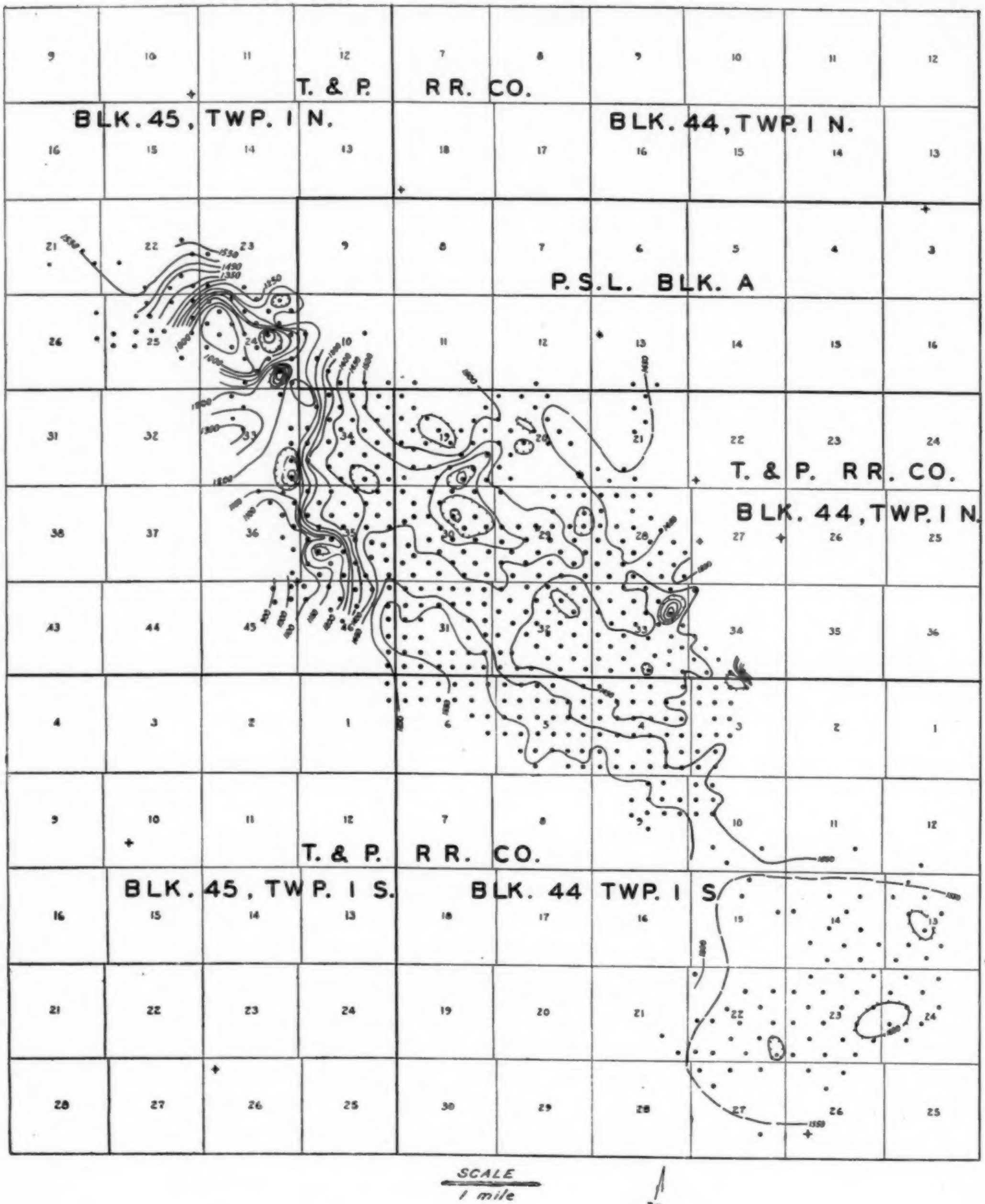

FIG. 13.—Bottom-hole pressures, Goldsmith field, as of June, 1938, corrected to 800 feet subsea. Contour interval is 50 feet.

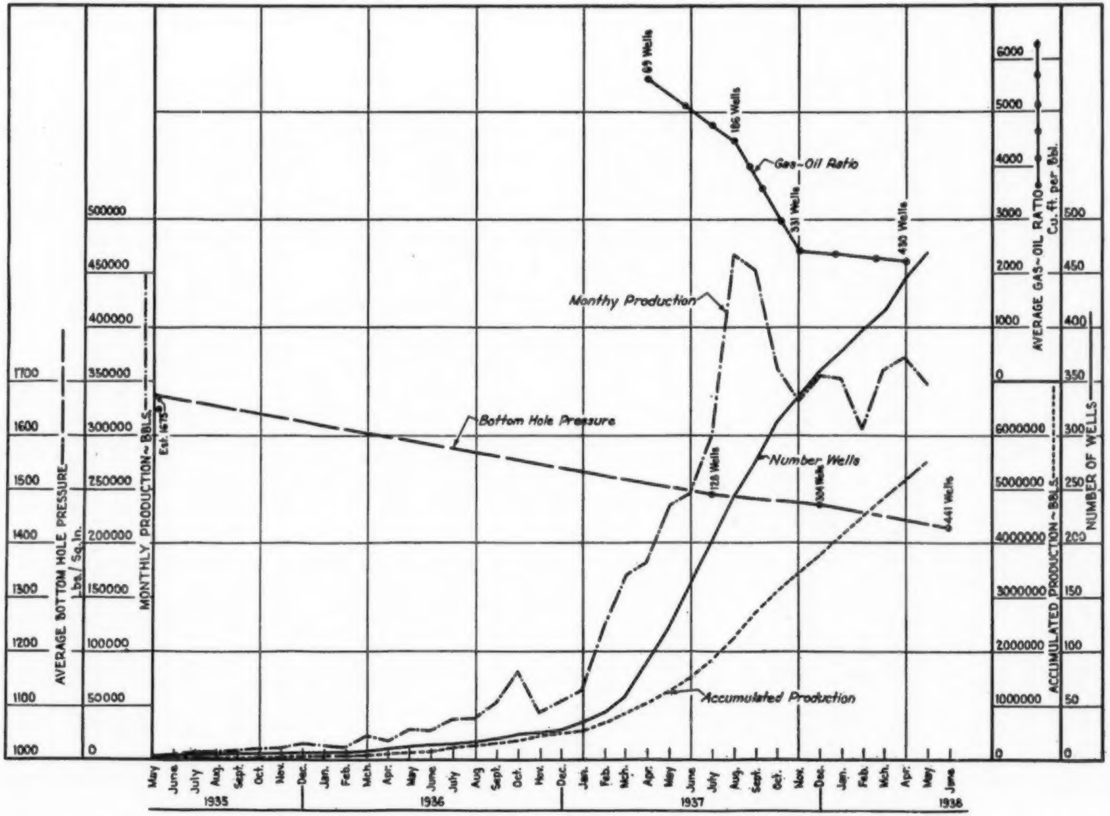

FIG. 14.—Gas-oil ratio, bottom-hole pressure, number of wells, and accumulated production curves, Goldsmith field, for period of May, 1935, to June, 1938.

Bottom-hole pressure.—A bottom-hole pressure map at 800 feet subsea as of June, 1938, is shown in Figure 13.

The composite curve of the Goldsmith field (Fig. 14) shows the bottom-hole pressure decline of the field, compared with monthly withdrawals, accumulated production, number of wells, and the weighted average gas-oil ratio by surveys.

Proration.—The proration order in effect in the field distributes the field allowable to 20-acre units on the basis of 50 per cent acreage and 50 per cent potential. Wells are spaced to give a 20-acre spacing by two different plans: wells may be located 440 feet from property lines and 880 feet apart, the result being that a 160-acre tract will take 8 wells, the center location being left undrilled; or, wells may be located 330 feet each way from two diagonally opposite corners of 40-acre tracts, this "staggered" plan also resulting in 8 wells to each 160 acres.

The potentials of wells are established by 12-hour tests, the 24-hour potential being the product of the last 6 hours' production multiplied by 4.

As mentioned under "Gas", the allowable production of wells with high gas-oil ratios is further limited by the gas displacement factor.

ACKNOWLEDGMENTS

The writers are indebted to R. K. DeFord, J. M. Hills, and J. E. Adams for helpful criticism of the manuscript; to Dowell Incorporated and the Goldsmith Engineering Committee for some of the data; and to the Landreth Production Corporation for permission to publish this report.

DISCUSSION

RONALD K. DEFORD, Midland, Texas (discussion received, June 19, 1939). In the projected West Texas-New Mexico symposium a scheme of sedimentary nomenclature is used that involves new names as well as names already widely known. Many readers will like to know how this scheme is to be applied to the described section of the Goldsmith field.

The manuscript of this excellent paper was read in advance of publication by several of the Midland, Texas, geologists who are helping to edit the symposium. The following is a sort of consensus of Midland geologists on the proper correlation,—that is, it is an editorial and not a personal comment.

The true base of the Rustler formation is probably at the base of the sand at 1,600 feet in Figure 2.

The new names that will be proposed in the symposium are: Dewey

Goldsmith Paper (Figs. 2 and 3)	*Symposium*
Lower Cretaceous	Lower Cretaceous
"Basement" sands	Paluxy sandstone
Triassic	Triassic
Dockum group	Dockum group
Red shale	Chinle shale
Santa Rosa sandstone	Santa Rosa sandstone
Red shale	Tecovas silt
Permian	Permian
Red silt	Dewey Lake red-beds
Upper evaporite	
Rustler anhydrite	Rustler formation
Main salt	Upper Castile (or Salado) halite
	Whitehorse group
Lower evaporite	
Anhydrite	Tansill formation
Yates sand	Yates sand
Anhydrite, *et cetera*	Seven Rivers and Queen formations
Dolomite section	
"Sandy Gray" dolomite to "North Cowden" sandy zone, inclusive (Fig. 3)	Grayburg formation
"White Crystalline" dolomite and "Brown Anhydritic" dolomite (Fig. 3)	Upper San Andres limestone

Lake by Page and Adams; Tansill by DeFord, Riggs, and Wills; Grayburg by Dickey.

E. Russell Lloyd, Midland, Texas (discussion received, June 19, 1939). The origin of porosity in dolomitic limestones is a problem which has not been solved satisfactorily and is a subject deserving extended research. The authors of the paper on the Goldsmith field present certain lines of evidence which, in their opinion, indicate that the porosity at Goldsmith was developed by subaerial erosion and solution during a break in deposition now marked by an unconformity.

I have long favored the theory that porosity as developed in the Permian dolomitic limestones of West Texas and New Mexico is essentially primary porosity developed contemporaneously (reef limestones, oölites, coquinas and lime sands), or quasi-contemporaneously (dolomitization), with the deposition of the limestones. Such primary porosity would obviously be modified by circulating waters. In some places openings would be enlarged by solution; more commonly they would be restricted by cementation and by deposition of calcite and anhydrite as cavity linings. Restricted porosity in some parts of the Goldsmith field is explained largely by deposition of secondary anhydrite.

The evidence presented regarding the Goldsmith field is not sufficient, in my estimation, to warrant a modification of my theory. Porosity in this, as in many other fields of West Texas and New Mexico is found from a few feet to several hundreds of feet below a pronounced unconformity. This is readily explained by the theory of primary porosity but not so easily explained under the theory of porosity developed by erosion and solution.

The problem is a highly important one to the oil industry and deserves extensive study. All lines of evidence—and they are many—should be thoroughly investigated and the results analyzed dispassionately. It is only by such thoroughgoing research and analysis that we may reach a satisfactory explanation of the origin of limestone reservoirs.

BULLETIN OF THE AMERICAN ASSOCIATION OF PETROLEUM GEOLOGISTS
VOL. 23, NO. 10 (OCTOBER, 1939), PP. 1553-1559, 4 FIGS.

TYPE LOCALITY OF CITRONELLE FORMATION CITRONELLE, ALABAMA[1]

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ABSTRACT

The type locality of the Citronelle formation, as designated by Matson in 1916, is significant mainly because of the exposure of plant-bearing clays near Lamberts Station about 5 miles south of Citronelle, Alabama. The flora from these clays was correlated with the Pliocene by Berry. Recent studies have shown that these clays are faulted and overlain unconformably by the sands of the so-called Citronelle formation. The structural evidence indicates that the clays are older than the sands so that the flora of the clays can not be used to correlate the sands. It is suggested that the term Citronelle, as a formation name, be dropped.

INTRODUCTION

In November, 1936, the writer visited the type locality of the Citronelle formation with a group of faculty members and graduate students from Louisiana State University. On this occasion their observations at the fossil plant locality, near Lamberts Station, indicated that the plant-bearing clays were not a part of the Citronelle formation. At the suggestion of Professors H. V. Howe and R. J. Russell the writer made two additional visits to this locality during the winter for more detailed observations. To William Romans, to the members of the field party mentioned, and especially to Professors Howe and Russell the writer is indebted for assistance in the field and also in the preparation of this paper.

Matson,[3] the author of the term Citronelle, chose the town of Citronelle, Alabama, as the type locality "because of the excellent exposures of the formation in its vicinity, especially to the north along the railroad for a distance of 3 or 4 miles." Added significance of this area as a type locality is the presence of plant-bearing clays, which Matson believed to be a part of the Citronelle formation, exposed in a railroad borrow pit at Lamberts Station about 5 miles south of Citronelle. It was from these clays that Matson collected all but two of the plant fossils used by Berry[4] to determine the Pliocene age of the Citronelle.

It is the purpose of this paper to bring out the relationship of the

[1] Read before the Association at New Orleans, March 16, 1938. Manuscript received, June 3, 1938.

[2] School of Geology, Louisiana State University.

[3] G. C. Matson, "The Pliocene Citronelle Formation of the Gulf Coastal Plain," *U. S. Geol. Survey Prof. Paper 98* (1916), pp. 167–92; abst., *Washington Acad. Sci. Jour.*, Vol. 6 (1916), p. 663.

[4] E. W. Berry, "The Flora of the Citronelle Formation," *U. S. Geol. Survey Prof. Paper 98* (1916), pp. 193–208.

plant-bearing clays to the sands and gravels at the Lamberts locality. It is believed that this relationship precludes the possibility of accurately dating the sands and gravels by means of the fossil flora in the clays.

DESCRIPTION OF LAMBERTS LOCALITY

The borrow pit is located along the east side of the Mobile and Ohio Railroad tracks at mile post 27 (27 miles north of Mobile). The pit is about 500 feet long parallel with the tracks and averages about 100 feet wide. The floor of the pit is level with the tracks except for the southern third which has been dissected by recent erosion. The eastern wall is about 20 feet high (Fig. 1).

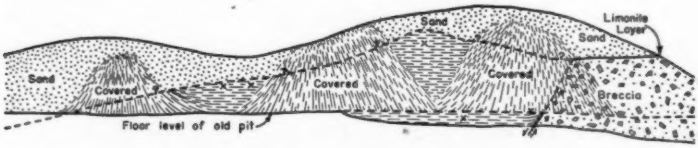

FIG. 1.—Composite section of wall of borrow pit and drainage ditch along track. Horizontal scale, 1 inch equals approximately 100 feet; vertical scale, 1 inch equals 25 feet. *X* indicates places where fossil plants were collected.

The best exposure of the plant-bearing clays is in the drainage ditch along the tracks at about the middle of the pit. Smaller and more weathered outcrops of the clays occur in the cliff at the back of the pit (Fig. 1). The clay beds at their southernmost exposure in the ditch strike N. 45° E. and dip 18° NW. (Fig. 2). About 50 feet north in the same ditch the clay beds are essentially horizontal.

South of the clay exposures in the ditch, erosion has exposed the material underlying the south end of the pit. This material is a "breccia" consisting of subangular fragments of interlaminated red clay and white sand in a matrix of white sand. These fragments vary in size from small pebbles to blocks 18 inches in greatest dimension. This same "breccia" material is exposed in the cliff at the back of the pit near the south end. On the hillside at the south end of the pit this "breccia" crops out at the surface whereas at the top of the hill it is overlain by about 6 feet of sand and gravel.

The plant-bearing clays are separated from the "breccia" by a fault which is well exposed in the drainage ditch and in several adjacent gullies (Fig. 3). The fault plane is marked by a thin layer of "sand rock" which is firmly cemented with limonite. The attitude of the fault plane is not easily determined but several readings taken on the indurated sand rock average N. 60° E. for the strike, and dip readings and bore-hole evidence indicate a dip of about 60° N. No means was found for determining the true stratigraphic displacement

on the fault, but the evidence available indicates a minimum of about 20 feet. The relatively steep dip of the clays near the fault plane and in the same direction as the dip of the latter is interpreted as a drag effect and indicates that the fault is normal. The origin of the "breccia" material is not clear but the large volume of the material seems to preclude the probability of its being a fault "breccia." The nature of the fault does seem to indicate that the "breccia" is older than the plant-bearing clays.

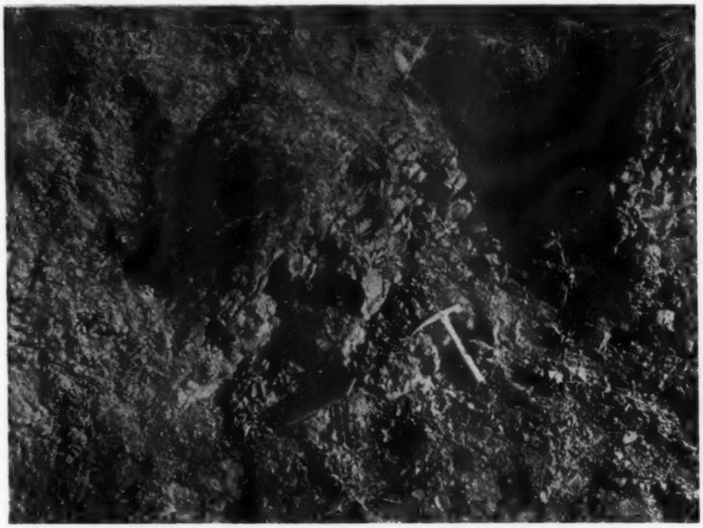

FIG. 2.—Dipping beds of fossiliferous clays exposed in drainage ditch just north (left) of exposure of fault plane. (See Fig. 3.)

Fossil plants similar to those in the track-side ditch were collected at several places along the cliff (Fig. 1). At one place (Fig. 4) the clays are sandy and overlain with a distinct unconformity by the sands and gravels above. That the sands are younger than the faulting of the clays is indicated by the fact that the sand beds pass over the fault without evidence of disturbance. In the immediate vicinity of the fault the base of the sands is marked by a layer of "sand rock" about 3 inches thick which is not affected by the fault.

AGE OF PLANT-BEARING CLAYS

Berry[5] has shown that the plant-bearing clays should be correlated with the Pliocene. A small collection of these plants was sent to Wil-

[5] E. W. Berry, *op. cit.*

liam Darrah[6] at Harvard University who concluded that they were either Pliocene or perhaps late Miocene in age.

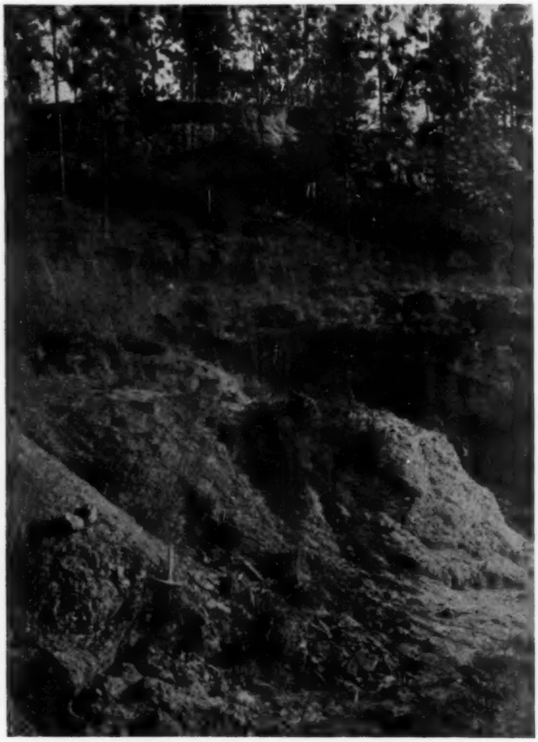

FIG. 3.—Exposure of fault plane in drainage ditch (lower left). Clays left and white sands of "breccia" right. Outcrops of sand rock marking fault may be seen in gullies in middle foreground and beneath figure in background.

RELATIONSHIP OF LAMBERTS LOCALITY TO EXPOSURES NORTH OF CITRONELLE

The exposures which Matson designated as the type locality of the Citronelle are found chiefly in cuts along the Mobile and Ohio Railroad north of the town of Citronelle. These exposures consist mainly of coarse sands with subordinate amounts of gravel, and locally, thin clay lenses. The exposures are so closely spaced along the tracks that it is possible to trace the sands and gravels from the type locality to

[6] Personal communication, 1937.

Lamberts without serious interruption. There seems to be no reason to doubt that the sands and gravels at Lamberts represent the same period of deposition as those north of Citronelle.

The writer has examined all of the cuts from a point 5 miles north of Citronelle to mile post 26 a mile south of Lamberts and in none, except the one described, did he find plant-bearing clays.

FIG. 4.—Exposure in back of pit showing sandy, plant-bearing clays overlain unconformably by coarse sands and gravels (dark).

AGE OF SANDS AND GRAVELS

The essential agreement of Berry and Darrah concerning the age of the clays at Lamberts leaves little doubt that the clays are at least as old as the Pliocene. The evidence presented here indicates that the sands and gravels which Matson called Citronelle are younger than the clays and therefore Pliocene or younger. In discussing these deposits with Gulf Coast geologists the writer has found that in general they consider the so-called Citronelle to be Pleistocene. In the literature most writers have followed Matson and placed the Citronelle in the Pliocene.

FUTURE USE OF TERM CITRONELLE

The term Citronelle is now widely used by Gulf Coast geologists to designate the oldest of the surface gravel and sand deposits in

Alabama, Mississippi, and Louisiana, as contrasted with the younger Beaumont and Port Hudson formations and terrace deposits. Doering[7] has recently proposed the name Willis for these deposits, giving the town of Willis in Montgomery County, Texas, as the type locality. In Texas the Willis rests on the Goliad formation which contains Pliocene fossils and is overlain by the Lissie formation which contains Pleistocene fossils. Doering concluded that the Willis must be either late Pliocene or early Pleistocene. He recognized widespread gravel deposits landward from the outcrop of the Willis ("Willis cuesta") and considers them to be residual deposits "derived largely from the destruction of the interior extensions of the Willis formation." He also recognized the unconformity between the plant-bearing clays and the overlying sands at Lamberts Station. As his term Willis is intended to replace the term Citronelle he proposes a new usage for the latter term.

> Since it would be convenient to have a name for this interior type of residual deposit, the writer [Doering] suggests the restriction of the name "Citronelle" to this usage. This restricted usage would still fit the type locality and a greater part of the "formation" which has been called by this name.

After presenting this paper at the New Orleans meeting of the Association, the writer had an opportunity to discuss the problem with both Matson and Doering. Doering was kind enough to supply written comments on his present views. Since publishing the paper already referred to, Doering has mapped areas in south Mississippi and southwestern Alabama, including the Citronelle area. He has concluded that the sands and gravels at Citronelle are really Willis and not younger as he had previously thought.

Doering suggests in his written comments[8] that "we must decide between the names Willis and Citronelle." This involves, of course, the assumption that his reconnaissance mapping of the Willis is correct.

With regard to priority it seems that the term Citronelle should be retained in preference to Willis. However, the same might be said, on the same basis, for the terms Lafayette, Diluvium, Orange sand, and others which were in common use before Matson proposed Citronelle. On the other hand, the same criticisms can be made of the term Citronelle that were made of the older terms. The type locality of the Citronelle is imperfectly described. The term has been misused when

[7] John Doering, "Post-Fleming Surface Formations of Coastal Southeast Texas and South Louisiana," *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 19, No. 5 (May, 1935), pp. 651–88.

[8] Personal communication, 1938.

applied to deposits which are not correlative with the type locality. The type locality seems to include more than one formation, that is, the plant-bearing clays and the overlying sands.

The writer is not prepared to accept Doering's conclusion that the sands at Citronelle can be correlated with his Willis formation in Texas. This correlation must await the completion of detailed mapping by means of which it may be possible to establish its validity. The writer is convinced that the principal difficulty in the terminology of these deposits is the lack of detailed mapping in wide areas. Surface sand and gravel deposits similar to those discussed by Matson and Doering occur throughout the Gulf Coastal Plain. The mapping and correlation of these deposits are primarily physiographic problems due to the general absence of indigenous fossils and also to the fact that they mantle rocks of various ages from Paleozoic to Pliocene(?). Due to the lack of accurate topographic maps for much of the Gulf Coast, an accurate study of these deposits is almost impossible at present.

What seems to be a desirable solution to the question of names for these surface deposits will appear soon in a bulletin of the Louisiana Geological Survey by Fisk.[9] He recognizes a series of four terrace deposits in central Louisiana which he considers to be Pleistocene in age. The older of these terrace deposits consists of materials generally referrred to as Citronelle. Of interest here is his statement regarding the naming of these deposits.

> In Grant and La Salle Parishes, fluviatile equivalents of the coastwise [Pleistocene delta] sediments clearly reflect structural movements which separated the Pleistocene Series into distinct units. Local names given the fluviatile deposits in Grant and La Salle Parishes are not introduced to complicate the literature but to distinguish local stages of deposition. Individual deposits have not been traced for great distances as yet, and their only distinction is in their structural and topographic relationships. Until they are shown to be extensive units they cannot be considered formations. In this report, therefore, they are regarded as members of the Pleistocene Series and their relationship to meaningless formational terms is considered unimportant.

It seems useless at this time to try to apply any formational name to these deposits. The writer therefore suggests that the term Citronelle be dropped for reasons already given and also because it appears to be useless. The acceptance of any other formational name should await the completion of detailed mapping of wide areas and the demonstration that these deposits constitute a definite formation.

[9] H. N. Fisk, "Geology of Grant and La Salle Parishes," *Louisiana Geol. Survey Bull. 10* (1938), pp. 149–72.

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GEOLOGICAL NOTES

BOUNDARY BETWEEN OLIGOCENE AND MIOCENE[1]

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From time to time the question is raised as to where to draw the boundary between the Oligocene and Miocene in the United States. This is a question that has little practical importance because it does not affect in any way the local correlation of geologic formations in North America. The answer to it depends on, first, the decision as to where to draw the boundary in Germany and Belgium, where the Oligocene is typically developed, and, second, the accurate correlation of the Upper Oligocene and Lower Miocene beds of Europe with formations in North America. If there are intermediate beds in America that are not represented in Europe, then the placing of the boundary within those limits becomes a local problem.

Beyrich's original definition of the Oligocene included beds in Germany and Belgium that are now called Sannoisian, Rupelian, and Chattian. The next younger stage is the Aquitanian; then follow the Burdigalian and the Helvetian. The upper boundary of the Oligocene as drawn in the United States has been shifted from time to time with differing interpretations as to what is Oligocene and what Miocene in Europe (Table I). Dall regarded the Aquitanian and

TABLE I
SUPPOSED EQUIVALENTS IN EUROPE AND AMERICA

Beyrich 1854	*Dall 1898*	*Woodring 1928*	*European Divisions*	*West Indies*	*Florida*	*Georgia*	*Mississippi*	
Miocene	Miocene	Miocene	Pontian		Choctawhatchee formation			
			Sarmatian					
			Tortonian		?			
			Helvetian		Alum Bluff group			
	Oligocene		Burdigalian	?	?			
			Aquitanian	Anguilla formation	Tampa limestone			
Oligocene		Oligocene	Chattian	?	?	?	?	
			Rupelian	Antigua limestone	Suwannee limestone	Flint River formation	Vicksburg group	Chickasawhay marl
			Sannoisian	?	?	?		

[1] Manuscript received, March 14, 1938.

[2] United States Geological Survey.

Burdigalian as Oligocene and drew the line at the base of the Helvetian. Accordingly he classified the supposedly Aquitanian Tampa limestone and Chipola formation as Oligocene.[3] Woodring[4] regards the Aquitanian and Burdigalian as Lower Miocene and therefore presumably would draw the boundary at the base of the Tampa limestone. This is the current practice of the United States Geological Survey.

The Vicksburg group has been classified as Oligocene chiefly because it lies between the Eocene and the Miocene. The Antigua limestone of the West Indies is classified as Oligocene because it contains a large coral fauna that Vaughan regards as of Rupelian age. If this correlation is correct, at least part of the Antigua is Middle Oligocene. The equivalents in the United States appear to be the Suwannee limestone[5] of Florida, the Flint River formation of Georgia and eastern Alabama, and the Chickasawhay marl of western Alabama and eastern Mississippi, all of which, in the writer's opinion, are of Vicksburg age.[6] The last two units contain two species of *Lepidocyclina* and several mollusks in common with the Antigua. The Suwannee, the Flint River, and the Chickasawhay are therefore classified as Oligocene by the United States Geological Survey. This reference to the Oligocene is confirmed by their stratigraphic relations, for the Suwannee and the Flint River are known to be older than the Tampa, and the Chickasawhay appears to be their equivalent.

The final decision as to where to draw the Oligocene-Miocene boundary in the United States must await the firm establishment of intercontinental correlations.

[3] W. H. Dall, "A Table of the North American Tertiary Horizons, Correlated with One Another and with Those of Western Europe, with Annotations," *U. S. Geol. Survey Ann. Rept. 18* (1898), Pt. 2, table facing p. 334.

[4] W. P. Woodring, "Miocene Mollusks from Bowden, Jamaica," *Carnegie Inst. Washington Pub. 385* (1928), table facing p. 41.

[5] W. C. Mansfield, "Mollusks of the Tampa and Suwannee Limestones of Florida," *Florida Dept. Conservation Geol. Bull. 15* (1937), pp. 46–62.

[6] C. Wythe Cooke, "Notes on the Vicksburg Group," *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 19 (1935), pp. 1162–72.

CAMBRIAN INLIER IN NORTHERN ILLINOIS[1]

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Introduction.—During the summer of 1923 the writer was employed by the Illinois State Geological Survey to make a detailed

[1] Published by permission of the chief of the Illinois State Geological Survey. Manuscript received, July 30, 1939.

[2] State geologist of Virginia.

study and areal geology map of the Oregon Quadrangle. Oregon is located southwest of Rockford, about 80 miles west of Chicago and 30 miles south of the Wisconsin boundary. In the course of that work it was discovered that the structure and geologic relations of the Ordovician strata in the vicinity of Oregon were more complex than had previously been interpreted. More detailed work later in a small critical area, supplemented by laboratory studies of the sediments, led to the conclusion that certain beds previously considered part of the St. Peter sandstone were actually Cambrian, occurring as an inlier.

Exposed Cambrian beds had not been previously reported in Illinois, and these are the oldest beds known to crop out in the state.

Location of inlier.—The critical exposures were found along the east side of Rock River, opposite the town of Oregon and north of the bridge on State Highway 64. They are in the bottom of a small abandoned quarry from which limestone was taken, reputedly for the construction of the near-by dam on the river. The quarry is on the southwest slope, and near the crest, of a conspicuous ridge that trends northwest on the Rock River valley floor. The crest of the ridge near the quarry is about 90 feet above the river.

Local stratigraphy.—The strata of this part of Rock Valley and its immediate environs consist of St. Peter sandstone overlain by Platteville limestone, with a thin stratum of Glenwood sandstone intervening.[3] These formations are well exposed at several places on the west side of Rock River, west and northwest of Oregon. They crop out also along the east side of the valley, as along the upper slope about ¼ mile east and northeast of the old quarry.

The St. Peter lies with marked erosional unconformity on older formations, ranging down into the Cambrian. A small erosional unconformity between the Platteville limestone and the underlying Glenwood sandstone has been described.[4]

Outcrops on the valley-floor ridge, with few exceptions, are poor and meager. Less than 200 feet south of the quarry, on the southwest slope of the ridge, about 30 feet of friable light gray to white sandstone of typical St. Peter appearance is well exposed. This sandstone was first mapped by the writer as St. Peter. The next summer a glauconitic sandstone was discovered in the bottom of the quarry. Upon the

[3] Arthur Bevan, "The Glenwood Beds as a Horizon Marker at the Base of the Platteville Formation," *Illinois State Geol. Survey Rept. Investig. 9* (1926).

F. T. Thwaites, "Stratigraphy and Geologic Structure of Northern Illinois with Special Reference to Underground Water Supply," *ibid., Rept. Investig. 13* (1927).

[4] S. G. Elder, "The Contact between the Glenwood and Platteville Formations," *Trans. Illinois Acad. Sci.* Vol. 29, No. 2 (1936), pp. 164–66.

determination that the sandstone in the bottom of the quarry was almost certainly Franconia, the white sandstone was tentatively designated as Dresbach. Some recent restudy of this sandstone by George E. Ekblaw, who coöperated with the writer during the completion of the areal survey of the Oregon Quadrangle, has led him to conclude that it is actually St. Peter. In 1938 he found a Trempealeau-Franconia contact near, and at the same elevation as, the white sandstone.[5]

The quarry face exposes unfossiliferous, poorly bedded magnesian limestone that is undoubtedly part of the Trempealeau dolomite. The thickness of beds exposed is probably about 25 feet. At a short distance in front of the face, near the west edge of the quarry floor, a few feet of thin-bedded greenish gray sandstone is exposed. The sandstone, according to Ekblaw, is also found at the southwest corner of the quarry, under the limestone. The color is due to small grains of glauconite scattered through a mass of fine angular quartz sand. The sandstone was at once suspected as being Mazomanie or Franconia, a conclusion which was supported by laboratory examinations. The identification was confirmed by Thwaites when shown a sample of it some months later. The sequence appears regular and conformable.

Structure and geologic relations.—The Cambrian inlier is exposed at the approximate intersection of two major anticlines, the east-trending Oregon anticline and another one that trends north-northwest, probably the La Salle anticline. The Kankakee arch intersects these two structures at Oregon.[6] The Franconia beds in the quarry on the ridge dip 13° NE. The Platteville limestone along the brow of the upland on the east and northeast has dips that range from 16° to 41°, and from N. 70° E. to N. 40° E. Along the strike and on the northeast flank of the anticline on which the ridge is located, and west of Rock River north of Oregon, the St. Peter sandstone and the Platteville limestone show a diversity of local dips, ranging apparently from 19° to 32° NE. Not far distant the beds are approximately horizontal.

It was formerly thought by the writer that the structural details and the stratigraphic relations of the beds in this relatively small area on both sides of Rock River north and east of Oregon indicated that a pair of faults of northwest strike occur here. Although local faulting is probably present, later work by members of the Illinois State Geological Survey, in part the laboratory study of well samples by

[5] M. M. Leighton, letter of April 7, 1939.

[6] George E. Ekblaw, "Kankakee Arch in Illinois," *Bull. Geol. Soc. America*, Vol. 49, No. 9 (1938), Fig. 1, p. 1427.

Workman and in part field studies by Ekblaw,[7] has eliminated one of the faults tentatively postulated by the writer and has made the other one questionable. Ekblaw and Workman have shown by these later detailed subsurface studies "that all or most of the Prairie du Chien series was [is] absent in northeastern Illinois." They postulate "a major post-Cambrian, pre-St. Peter fold and erosion," which accords better with all the available evidence. The general relations are diagrammed in their Figure 3.

The present interpretation of the evidence is that in the vicinity of Oregon the St. Peter sandstone is abnormally thick and that it rests with marked erosional unconformity on beds in the Trempealeau and Franconia formations, filling, perhaps, a deep channel in the Cambrian beds. West of the river, the dip of the St. Peter sandstone carries it below the elevation of the Franconia beds in the bottom of the old quarry east of the river. The precise horizon of exposed glauconitic sandstone beds is unknown; thus the stratigraphic measure of the unconformity is indeterminate, but it may be of the order of 600–700 feet. The Cambrian inlier is on a "structural high," produced by the pre-St. Peter deformation. The course of Rock River across this structure at a critical locality exposes the Cambrian beds.

[7] George E. Ekblaw, *op. cit.*
George E. Ekblaw and L. E. Workman, "Relation of Water-Bearing Strata in Northern Illinois to the La Salle Anticline," *Illinois Soc. Eng. 45th Ann. Rept., Bull.* 5(2) (1930), pp. 63–67.

WASCO FIELD, KERN COUNTY, CALIFORNIA[1]

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A climax in the history of prospecting efforts in the Wasco-Semitropic district of California was reached, April 11, 1938, when the Continental Oil Company well No. K.C.L. A-2 was swabbed in to prove that oil could be produced at a substantial rate in the Wasco field from a zone encountered at 13,095 feet.

Well No. K.C.L. A-2 is in Sec. 8, T. 27 S., R. 24 E., M.D.B. & M., Kern County, California, approximately 26 miles northwest of Bakersfield and 4 miles due west of Wasco. It is 660 feet north of the Continental Oil Company well No. K.C.L. A-1 which had been producing a few barrels of oil per day from a shallower depth (9,591 feet) since April, 1937.

Considerable interest was created by well No. K.C.L. A-2 because

[1] Manuscript received, July 31, 1939.

[2] Continental Oil Company.

it was the first hole drilled to a depth of 15,004 feet; approximately 2,200 feet deeper, at that time, than the previous record depth. Production, however, came from a zone between 13,095 feet and 13,130 feet known as the "A-2 sand" member of the Rio Bravo sand. This was the world's deepest producing zone for a short time. On a 24-hour potential test the well flowed 3,663 barrels 35.7° gravity oil cutting 0.6 per cent, with 1,720,000 cubic feet of gas through one 1-inch bean, tubing pressure of 470 pounds, and casing pressure of 560 pounds. This well produced 139,535 barrels of oil during its first year cut back in accordance with proration allowables.

Wasco is a deeply buried closed structure of low relief along the northwesterly extension of the trend on which the Greeley and Rio Bravo fields are located.

The following is a generalized summary of the strata penetrated by well No. K.C.L. A-2, presented as an outline and without discussion.

	Well Depths in Feet	*Thickness in Feet*	*Lithology and Remarks*	*Formation*
RECENT	0– 497	497	Surface sand and gravels	Valley alluvium
PLEISTOCENE	– 2,820	2,323	Sands and silts with clays and hard shells. Dry gas showings, 2,200+ feet	Tulare
PLIOCENE	– 4,380	1,560	Claystone and silt. First *Mya* zone, 2,820 feet. Gas showings	San Joaquin clays
	– 7,882	3,502	Fine sands and silty shale. Top *Mulinia* zone, 4,380 feet, gas showings. Oil and gas showings at 7,120 feet	Upper Etchegoin
	– 8,440±	558±	Blue-gray shale. Base Pliocene sands and silts, 7,882 feet	Lower Etchegoin
UPPER MIOCENE	– 9,527	1,087±	Gray-brown shale	Reef Ridge
	–10,254	727	Hard, brown shale with cherty streaks. Oil showings, producing zone of well No. K.C.L. A-1	McLure shale
	–11,060	806	Hard, brown shale. First bentonite streak, 10,254 feet (*Pulvinulinella* fauna)	Lower Fruitvale shale
	–11,325±	265±	Hard, dark brown shale (*Valvulineria californica* fauna)	*Valvulineria* zone
	–11,500±	175±	Hard, brown shale	Gould shale
MIDDLE MIOCENE	–11,581	81±	Hard, dark brown shale (*Uvigerinella obesa* fauna)	Upper Temblor shale?
	–12,100±	519±	Hard, fine to medium, gray sand and siltstone. Slight oil staining near top	Upper Olcese sand (Temblor)

	Well Depths in Feet	*Thickness in Feet*	*Lithology and Remarks*	*Formation*
	−12,245	145±	Hard, dark gray siltstone	Middle Olcese silt? (Temblor)
	−12,715	470	Hard, medium to coarse, gray sand with streaks of shale and siltstone. Oil showings	Lower Olcese sand (Temblor)
	−13,095	380	Hard, dark shale and streaks of sandy shale (*Uvigerinella obesa* fauna)	Rio Bravo shale (Temblor)
	−13,568	473	Medium to coarse, gray sand. Production from A-2 sand, 13,095± to 13,130 feet	Rio Bravo sand
LOWER MIOCENE?	−13,800±	132±	Hard, dark shale with streaks of sand and siltstone (fauna inconclusive)	Santos shale?
	−14,000+	200±	Hard, fine sand and siltstone (no faunal data)	Vaqueros?
OLIGOCENE?	−14,162	162±	Hard, dark brown shale. Oil showings (*Leda washingtonensis* fauna)	Tumey shale
	−14,750±	588±	Hard, dark shale. Oil showings (*Uvigerina cocoaensis* fauna)	Upper Kreyenhagen
EOCENE	−14,967	217±	Hard, dark shale. Oil showings (*Spiroplectamina-radiolaria* fauna)	Lower Kreyenhagen
	−15,004	36	Hard, fine sand and siltstone with altered bentonite on bottom. Oil stains (no faunal data) 15,004 feet, total depth.	Avenal?

On July 15, 1939, there were five wells producing from the "A-2 sand," one drilling well, and two abandoned dry holes. To date the average completed well has encountered about 34 feet of very permeable rock in the "A-2 sand" from which it establishes a potential rate through a 1-inch bean of more than 6,000 barrels per day. Flow pressures, against the small beans through which the wells make their allowable production, range from 1,200 pounds to 1,400 pounds with the casing pressure being only a little higher than the tubing pressure.

It took well No. K.C.L. A-2, 234 days to penetrate the "A-2 sand" (284 days to completion), but 115 days is average time for subsequent holes. The quickest completion to date was made in 85 days.

Permeability and porosity of deep sands in the Wasco field have received some attention and in this connection it is interesting to note that generally all of the sands studied from the Olcese sand (11,500+ feet) down, except the "A-2 sand," have had very low permeability, ranging from less than 1 to 37 millidarcys, with porosity averaging close to 15 per cent. In the permeable "A-2 sand" (producing zone)

the range is from 130 to more than 2,000 millidarcys, with a porosity range from 12 to 24 per cent.

Productivity indices from 5.0 to 8.0 barrels per pound drop in pressure have been calculated, which is considered high for such a small thickness of zone. Original reservoir pressure at 13,134 feet, well datum, was determined as 5,675 pounds. To date no appreciable drop in this pressure is indicated. In all of the wells now producing, the oil is extremely undersaturated, indicating that either the field has no gas cap or that these wells are a long distance from it. When this information is correlated with that of the easily induced flow of salt water from the "A-2 sand" zone in a well beyond limits of production there is a strong suggestion that water drive is the lifting force.

Formation temperature of the producing zone has been carefully checked at 277°F. Temperature at bottom (15,004 feet) is estimated at 297°. There has been some comment about these being high but actually Wasco is a relatively cool area. A study of subsurface temperature data from 20 areas in California indicates Wasco is 16th from the hottest.

Credit for discovery of this pool is due to seismograph work for its structural control, subsurface study for stratigraphic control, and engineering progress in drilling and production technology which have made it possible to exploit petroleum resources at increasingly greater depths.

NEW LIBRARY RESEARCH TOOL[1]

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The recent spur to renewed research in the fields of interest to the petroleum geologist evidenced in these pages makes it seem timely to call attention to a recently developed tool for research workers. This tool is the microfilming of texts on film, usually regular cinema size of 35 millimeters, at low cost to make them available to research workers throughout the land. This service has been known and widely discussed in library circles for several years but conversation with members of the Association, even those actively engaged in research, reveals that many are still unacquainted with this means of having the world's library service available to all workers, no matter how remotely located.

[1] Manuscript received, August 1, 1939.

[2] President, Peninsular Oil and Refining Company.

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This new activity places added responsibility on writers in the matters of bibliography. Not only should the references be exact for the material quoted but both initial and final pages should be accurately numbered and above all the position of all plates should be indicated. If the plates are interleaved in the text they are usually microfilmed but if they are placed after the text the service does not ordinarily include their filming. Naturally all references should be sufficiently clear for library stock boys to identify them easily.

SALADO FORMATION OF THE PERMIAN BASIN[1]

WALTER B. LANG[2]
Washington, D.C.

The Delaware basin is a structural depression in western Texas and southeastern New Mexico. This depression was filled and overlain by chemical deposits of late Permian age which are now either partially eroded away west of the Pecos River, or, east of it, are masked from view by a covering of younger deposits. Most of the detailed information now at hand concerning these deposits has been obtained from the study of well cuttings and has disclosed that these sediments are divisible into two formations:[3] The lower, or Castile formation, is

[1] Printed by permission of the director of the Geological Survey, United States Department of the Interior. Manuscript received, August 31, 1939.

[2] Geologist, United States Geological Survey.

[3] W. B. Lang, "Upper Permian Formations of Delaware Basin of Texas and New Mexico," *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 19 (1935), pp. 262–70.

composed of typically banded anhydrite and calcite and in the northeast half of the basin includes thick beds of clean white halite. The upper, or Salado formation, occupies not only the eastern portion of the Delaware basin but spreads northward and eastward above and beyond the basin rim, which is formed by the Capitan reef. This upper formation, which is absent in most of the western half of the basin, is apparently exposed nowhere at the surface. It is composed essentially of halite with relatively thin beds of anhydrite, polyhalite, reddish sandy shale, and locally other potash-bearing salts. However, in southern Reeves and northwestern Pecos counties, Texas, the halite grades into massive anhydrite. Therefore, a complete section of the Castile and Salado deposits can be found only in the subsurface in the northeastern portion of the Delaware basin. Even here a section may not display all phases and aspects of the deposits. The Castile and Salado formations have also been referred to as the "Lower Castile" and "Upper Castile," respectively.[4]

In 1921, the Pinal Dome Corporation's Means well was drilled in the SE. corner, Sec. 23, Blk. C-26, P.S.L., slightly east of the center of Loving County, Texas, to a depth of 5,208 feet, and approximately in the middle of the northeastern half of the Delaware basin where a complete section of both formations is present. It was, and still is, one of the best sampled and analyzed standard cable-tool wells in the basin. Cuttings were taken every 5–10 feet and potash analyses were made of the salt section to 3,600 feet or through 2,700 feet of salt. In this and other wells drilled about the same time it was observed that showings of polyhalite extended downward in the thick salt sections only part way, but in the shorter sections outside the Delaware basin, underlain by the Carlsbad limestone and correlative deposits, polyhalite was found almost to the base of the salt. In the Means well evident showings of polyhalite are last observed at 2,340 feet. When the writer originally defined the Salado, he arbitrarily selected the figure of 2,350 feet as the base. At this time, only a few widely spaced wells had been drilled and correlation of the various anhydrite beds could not be made with certainty. In the light of additional evidence it is now desirable to redefine the base of the Salado.

This may be accomplished in several ways, four of which are worthy of consideration.

1. One method would be to place the lower boundary of the Salado at the "base of the salt," where it overlies the reef limestones and is

[4] L. D. Cartwright, "Transverse Section of Permian Basin, West Texas and Southeast New Mexico," *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 14 (1930), pp. 979–80.

separated from them by 50–100 feet or more of solid anhydrite; but, if this contact be extended into the basin, it lies at different horizons due to the interfingering of anhydrite with halite. Were it not for the interfingering this method would have merit, in that it is simple and easily applied. The chief point against it is that it is a temporary expedient and would soon fall into disfavor as the minute details of correlation continue to accumulate. In the Means well this contact may be selected at 2,965 feet.

2. The presence of potash in the form of polyhalite is an outstanding feature of the Salado. If the last showings of polyhalite in well cuttings are plotted they form a fairly regular horizon in the reef and back-reef areas but are far less consistent in the basin. For this reason, though the evidence is important, it is not in itself sufficiently reliable for the purpose of selecting boundaries. This lack of consistency is demonstrated in the Means well, for at 2,325–2,340 feet are two analyses showing respectively the presence of 3.10 and 3.31 per cent of K_2O in soluble salts and thus corroborating the visual evidence of polyhalite. These are followed to a depth of 3,600 feet by a succession of analyses, all showing results of less than 1.0 per cent of K_2O in soluble salts, though 500 feet or more of the section below 2,340 feet must be equivalent to salts that yield evidence of polyhalite at or near the area of the reef.

3. In like manner the first indication of banded anhydrite or of calcite reveals the presence of the Castile, though these features may not appear at the same horizon in different places because prominent banding or calcite may be lacking in the deposits, or because the observer may be unable to recognize them. In general, the top of the observed banded anhydrites forms a fairly uniform horizon, though in places the actual position of this banding may be far below its hypothetical position. Thus it is not well to place too much reliance on the observed position of the top of the banded anhydrites. The beds of typical, banded anhydrite do not extend beyond the basin but lap against the marginal reef deposits. In the Means well the banded anhydrites appear at about 3,400 feet.

4. If one surface is postulated to pass through the deepest indications of polyhalite and another to include the highest showings of banded anhydrite, a gap of 500–700 feet or more lies between them. Within this gap may be found a third surface that represents the stratigraphic position of the base of the beds that lie disconformably on the top of the reef. The top of the reef is a definite, recognizable, and continuous horizon, marking the top of the Capitan and Carlsbad limestones and the correlative beds of the back-reef. Immediately

overlying the limestone is a dense non-banded anhydrite, 50–100 feet thick. The top of this anhydrite is the so-called "base of the salt" in the reef and back-reef areas. The writer included this anhydrite in the top of the Castile in 1937.[5] Whether the top or bottom of this anhydrite member is chosen to separate the Salado ("Upper Castile" of some authors) from the Castile ("Lower Castile" of some authors) the boundary between the two units would be at a definite, fundamental stratigraphic position. The sedimentary characteristics that are typical of each formation would thus be placed in their proper province.

In redefining the Salado formation, the writer prefers to include the anhydrite as its basal member, for this anhydrite does not show any of the characteristics of the typical anhydrite beds in the Castile. It is in places magnesitic, dense, non-banded, and contains no calcite. If placed in the Salado it confines the Castile to the Delaware basin and eliminates the awkward situation of having to carry a thin strip of Castile across the reef and back-reef areas for no apparent good reason. Within the Delaware basin the horizon of the top of the anhydrite member is found in most well samples with no greater facility than the base. The base of the Salado formation in the Means well as redefined in this note is placed at a depth of approximately 3,300 feet or at a position equivalent to the base of the anhydrite member on the crest of the Capitan reef on the northeastern rim of the Delaware basin.

[5] W. B. Lang, "Permian Formations of the Pecos Valley of New Mexico and Texas," *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 21 (1937), pp. 833–98.

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DISCUSSION

PLANNED GEOLOGIC FIELD EXPERIENCE[1]

JOHN B. LUCKE[2]
Morgantown, West Virginia

In his recent editorial, "Where Shall Our Young Graduates in Petroleum Geology Acquire Field Experience?," F. H. Lahee[3] has raised a most important question. The problem has, of course, always been before geology educators, but a satisfactory answer has been harder to find since 1929, and now it apparently is also giving concern to industrial geologists. As one with some experience both in oil geology and the teaching of potential oil geologists the writer offers a few suggestions as possible or tentative "answers," hoping that others will contribute discussion until a final solution be found.

All through the depression large numbers of young geologists accepted oil-company jobs which promised little in the way of a future. They received salaries that were woefully inadequate for men and women of their high degree of technical training. A large number of others have been forced to embrace surveying, soil mapping, meteorology, and other non-geologic fields which, although entirely worthy in themselves, merely served as stop-gaps. The aspiring young geologist hoped they could furnish experience to make him more acceptable to those "in the driver's seat" in his chosen profession.

Such a moratorium of jobs has not been peculiar to this profession, or even to its commercial phases, but the greatest excess of ability over opportunity is probably in the field of petroleum geology. Nevertheless, students with a serious bent for oil and gas geology and good potential material seem to be increasing in numbers in the face of present conditions. A large majority of them can not afford to proceed, unaided, to the doctorate degree and many are unfitted by temperament to become research geologists. They are good oil-company prospects, but after graduation they are met more and more frequently with the company geologist's dictum: "We don't want men with little or no practical experience. If you only know geology from college, go out and get experience in the field and we'll consider your application."

In the Gulf Coast area, as Lahee said:[4] "There is almost no opportunity for a young graduate to obtain experience in field geology, and yet, to build up the background which will be essential to his usefulness as a subsurface geologist, he must somehow get this field experience." Lahee[5] assured the writer that he meant by "experience in field geology" not facility with a plane table or any other technique available through organized instruction,

[1] Presented before the Geology and Mining Section, West Virginia Academy of Sciences, at Charleston, West Virginia, May 5, 1939. Manuscript received, August 3, 1939.

[2] Assistant professor of geology in West Virginia University.

[3] F. H. Lahee, "Where Shall Our Young Graduates in Petroleum Geology Acquire Field Experience?" *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 22, No. 11 (November, 1938), pp. 1613–14.

[4] F. H. Lahee, *op. cit.*

[5] F. H. Lahee, personal communication to the writer, April, 1939.

but rather a breadth of geologic experience without which an oil geologist (or any other, for that matter) is ill-equipped to work in diverse regions and to develop the judgment necessary to render decisions affecting valuable properties.

Another prominent geologist recently told the writer that in his opinion the day has arrived when oil companies will hire only geologists who hold the doctorate degree or its equivalent in field experience. One hesitates to accept such a pessimistic view. Doctoral training for a scientific career is by no means precisely suited to petroleum geology practice and the fact that many recent Ph.D's in geology have gone into oil work does not necessarily signify that a satisfactory precedent has been established. It seems that predictions as to the future for petroleum geology based upon ten consecutive depression years should remain subject to revision.

While investigation of supply and demand may result in evidence that our colleges and universities are over-producing young geologists, this conclusion is not yet justified by available facts. It certainly should not be embraced until efforts to correct glaring deficiencies in the present set-up have been made. If such efforts fail, then no other conclusion than over-production becomes possible.

The following suggestions are offered in the hope that they may stimulate further discussion of both academic and commercial viewpoints, leading toward some amelioration of the difficulties.

1. PLANNED APPRENTICESHIPS

Many industrial organizations, dependent on technology, especially in the various branches required in manufactures and public utility service, have instituted "cadet" or "engineering apprentice" training systems. Graduates of promise, hired under such a system, are trained by the company to make them effective in its business as early as possible and to serve as a reservoir of recruiting replacement for all of its key-men. During this time they receive a very low salary, subject, however, to reasonable increases in cases where ability is shown. Meanwhile, the recruit is constantly shifted through various departments, doing both common-labor and white-collar assignments. Best of all, if "he has the goods" and "can take it," as the saying goes, he is assured of a safe and useful future. If he has suitable personality characteristics, his broad foundation of experience may enable him to rise to executive status, assuming other ability is clearly demonstrated. The writer knows of no such training plan being instituted by a major company in mineral fuels, at least as far as geology is concerned.

Such a planned apprenticeship training system should be entirely feasible in the geological department of a large petroleum company. In spite of the statement by Lahee previously quoted, there are very few kinds of geologic field work which can efficiently be done by just one man. Many prominent geologists today "cut their eye-teeth" as helpers or assistants to older men, and it often meant a long period of merely carrying the instruments, cutting and labelling samples, or similar drudge work.

Even if commercial geologists must do very specialized work today, they should attain a larger *ultimate* value to a major oil company if the first few years were spent in getting acquainted with many diverse problems and areas likely to be encountered in future years. It is suspected that for every such

cadet who "can't take it," or lacks "the goods" and quits, thereby incurring a loss to the company, there will be at least one good enough and willing to stay with the company. In the long run he will be more valuable to the company than one who is hired as a specialist and kept forever at his specialty.

Objections to such a plan may center around too high a cost in dollars or man-hours, or both. The reply would seem to be that if it works successfully in other fields, why not in oil? The cost per training year is not important. The cost of assuring the most competent staff is what matters and this may well be least with the highest yearly training expense. Incidentally, loyalty to the company would be immensely stimulated in anyone who had been through a planned apprenticeship at the expense of the company and this is an asset that can not be measured in dollars.

2. SUBSIDIZED INDEPENDENT FIELD WORK

Most students, including the best raw material, have a struggle to finance their regular college work, let alone graduate studies, and least of all summer field work. Professional bodies such as the Geological Society of America, this Association, the National Research Council, as well as a few of the most favored universities, grant money to promising geologists for research work. Ordinarily nearly all of these grants are for "pure science" studies, leading either to a higher degree or to an enhanced scientific reputation. Why not have similar grants for "applied science" or professional practice, to be utilized for the acquisition of the practical training that industry demands?

Perhaps the purely scientific or professional bodies mentioned should not undertake such projects, since their purposes are divorced from industry, which must earn profits or cease to exist. However, if the training is to be done by university faculty men, it must be financed by the universities themselves, or the industries concerned, or both. The American Association of Petroleum Geologists might well act as a clearing house or directing body for oil and gas training. In such a rôle, this Association might systematically steer geology-thesis studies into the many unsolved problems recently suggested by a large part of the membership. There would doubtless be weaknesses in such a plan. For example: companies supporting the training might disagree about the work needed; they might disagree as to which is to have the pick of promising youngsters; they might even display a tendency to favor students of a particular school or of a particular professor over others. However, if industry insists on trained men and women and remains unwilling to do the job itself, it should be eager to support such work elsewhere, both financially and in an advisory capacity. Industry itself is a most interested party and each division must support itself.

Heavily endowed universities might well divert money hitherto reserved for pure science into such projects. As for state universities (in general) and other institutions with little or no endowment facilities, they apparently would have to lean heavily upon the support of industry. The mineral industries may find it expedient and even profitable, in the long run, to set up training funds at such state institutions as can best serve them, to be utilized as they direct, for the assistance of students of exceptional promise, as discovered by their professors.

3. SUBSIDIZED SUMMER CAMPS

A few colleges and universities, fully cognizant of the crying need for field

experience, maintain summer geology "camps" at which students may acquire practical field techniques and familiarize themselves with the variety of geology available at the camp location. Most of these camps grant course credit and are not designed for training of commercial grade. Such geology camps can be of the largest benefit to industry only if and when students are relieved of at least part of the cost through its assumption as an investment by the sponsor. If the sponsor (as now is usual) is a college or other research body, the student will be groomed for other than industrial needs, perhaps to the exclusion of such needs. The fact that many men do acquire the background demanded by industry is in spite of the system, rather than because of it. Work done in camps sponsored by industry could be deliberately directed along the lines of highest practical importance to the man and especially to the industry.

Thus in a hypothetical geology camp, the sponsoring company might supply part or even all of the faculty from its own staff, or subsidize and pick university men as it chose. The result would be far more purposeful field work than is now being done, from the commercial standpoint, and that of national economics. Even if industry proves unwilling to pay college men summer salaries or expenses for such training periods, it is believed that there are many professional geologists who would embrace an opportunity to serve at such a summer camp without salary, provided the sponsors met all running expenses, assisted students to pay their share, and afforded the "faculty" opportunities to carry on independent research on the side.

These remarks are in no way intended to neglect the few training "schools" or laboratories maintained by some companies for specialized training of, for example, petroleum engineers, micro-paleontologists, geophysicists, and safety engineers. Many companies are alert to the need for developing their own men in these and other special fields of work. But, the only way to acquire field geology is *in the field*, and the situation cited by Lahee has not received adequate attention.

EVIDENCE OF EROSION OF SALT STOCK IN GULF COAST SALT PLUG IN LATE OLIGOCENE

CORRECTION

The writer regrets a mistake in the paper published under this title in the April *Bulletin* (Vol. 23, No. 4). Apparently in inserting the sections of Figure 1 and 2 in the manuscript the writer reversed the sections. The section published with Figure 1 description (cut line) should have been with Figure 2 description (cut line), and the section published with Figure 2 description should have been with Figure 1 description.

MARCUS A. HANNA

HOUSTON, TEXAS
April 20, 1939

BULLETIN OF THE AMERICAN ASSOCIATION OF PETROLEUM GEOLOGISTS
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REVIEWS AND NEW PUBLICATIONS

* Subjects indicated by asterisk are in the Association library and available to members and associates.

A TEXTBOOK OF GEOMORPHOLOGY BY PHILIP G. WORCESTER

REVIEW BY A. O. WOODFORD[1]
Claremont, California

A Textbook of Geomorphology, by Philip G. Worcester. 565 pp., 375 figs. D. Van Nostrand Company, New York (1939). Price, $4.00.

Professor Worcester states in his preface that this book "has been planned for an introductory course in geomorphology and assumes little or no previous knowledge of geology on the part of the student." Geomorphology is defined as "the interpretative description of the relief features of the earth." The subject matter does not include meteorology, except incidentally. The volume has many merits as a textbook and will be very useful, even though the first chapters, in particular, are crowded with more information than beginners can absorb in a brief college course. Some things might well have been omitted, and others might have been relegated to appendices.

The experienced geologist probably will be interested especially by two features of the book, the many magnificent illustrations and the detailed discussions of topics of current geomorphic interest. He will also be grateful for the numerous references to sources. The photographs are very well reproduced. Many are air views. Colorado, the author's home state, and Canada are especially well represented. Other notable photographs are from the Mississippi River Commission, Milwaukee Public Museum, and the American Geographical Society's "Peru from the Air." Desert ranges are shown by Spence Air Photos, and desert details from the camera of Eliot Blackwelder. Views of far countries are largely by D. F. Higgins. The non-photographic illustrations are mostly maps (many two-color, with contours) and well chosen physiographic diagrams.

Subjects of recent geomorphic emphasis which are treated in some detail include submarine canyons, coral reefs, pediments, channeled scablands, causes of glaciation, and the origins and histories of the Great Lakes, the Appalachians, and the southern Rockies. The discussions are clear, and remarkably complete and up-to-date. The recency of some source material is shown by the following examples. Fisk's 1938 correlation between Mississippi delta terraces and Pleistocene interglacial epochs is presented for consideration, p. 200. Sir George Simpson's 1938 attempt to explain ice ages is given a page of text, an illuminating figure, and the author's cautious approval.

Some minor defects of the book may be worth mention. A few vague or confusing statements contrast strangely with the prevalent sharp clearness. Examples: "*Syenite porphyry* refers to a syenite with contrasting grains," p. 75; baselevel is "an imaginary curved plane at sea-level elevation," p. 178; "*The Profile of Equilibrium.*— . . . There is a nice adjustment between the stream's ability to erode the land and the amount of erosion yet to be done," p. 179.

[1] Department of geology, Pomona College. Manuscript received, July, 1939.

Other statements appear to be incorrect. Examples: "All seashores experience high tides every 12 h. 26 m.," p. 380; mature streams "may or may not have cut their valleys to baselevel," p. 190; the Plateau of Quebec has an "area of more than 2,000,000 square miles," p. 303. Undertow (p. 378) is inadequately defined and discussed. The Salton Sea depression appears to be incorrectly interpreted (p. 345) as simply a part of the Gulf of California cut off by the growth of the Colorado delta.

The reviewer considers the discussion of the work of streams (especially pp. 163–179) to be the least satisfactory part of the book. The photographs and diagrams are good as far as they go, and most but not all of the terms used are clearly and accurately defined. By reading pages 163–179 the careful student will learn, if he does not know already, just what is meant by the term delta or pot hole or braided stream, or even baselevel. But he will barely begin to understand the process by which streams achieve (and progressively alter) unstable equilibrium conditions. Probably he will fail to grasp the stated interrelationships between slope, form of cross section, straightness and smoothness of channel, and velocity. He may not know what is meant by "the stream's power to move objects on the bottom," especially as competence and capacity are confused in the course of the brief explanation.

The analysis of the flow of a débris-laden stream is a most difficult matter. Probably it should not be attempted for elementary students. If the attempt is made, it must be remembered that the typical beginner in geomorphology knows almost nothing about any science. He must be instructed as to the acceleration of gravity and its resolution into components, the conservation of energy, friction losses, and states of flow with emphasis on turbulence. Then he may be brought to some understanding of the development of meanders or the equilibrium profile.

The reviewer is prejudiced against the attractive treatment of "rejuvenation in arid regions," pp. 255–259, because of one omission. It is stated that "in many arid basins the great aprons of alluvium (bajadas) that lie at the base of the mountains are deeply channeled by streams. Where there is no evidence of diastrophism, it is evident that the channels are due to streams revived by heavy rainfall." But in such cases fanhead trenches may be features of an undisturbed arid or semi-arid cycle; they do not necessarily indicate either diastrophism or climatic change.[2] Finally, the allegation on page 257 that "rejuvenation in arid regions is brought about . . . through . . . (2) increased precipitation, (3) decreased rainfall . . . " is reminiscent of the traveller who blew on his fingers to warm them, and on his porridge to cool it. The quoted statement arouses a curiosity which is not satisfied in the text.

In brief, Worcester's Geomorphology is an attractive, informing, up-to-date book, which in spite of some defects makes a useful addition to the geologist's library.

[2] R. Eckis, "Alluvial Fans of the Cucamonga District, Southern California," *Jour. Geol.*, Vol. 36 (1928), pp. 224–47.

A SOURCE BOOK IN GEOLOGY, BY KIRTLEY F. MATHER AND SHIRLEY L. MASON

REVIEW BY R. D. REED[1]
Los Angeles, California

A Source Book in Geology, by Kirtley F. Mather and Shirley L. Mason. A volume in the series, *Source Books in the History of the Sciences*, Gregory D. Walcott, general editor. McGraw-Hill Book Company (1939). 702 pp., 42 figs., guide to subject matter, and index. Price, $5.00.

If an editor were to select and publish in a volume the most effective sections from the greatest, most stimulating, and most historic publications that deal with geology, the result would be a source book. It would naturally not fully please anybody who had already made such a selection for himself, nor would its merits be very evident to those who had failed to make one. With these and other inevitable difficulties the Mather-Mason book struggles masterfully.

This book differs notably from Agar, Flint, and Longwell's *Geology from Original Sources*, which also contains some selections of historic interest, but which is primarily a book of collateral reading for an elementary course in geology. The Mather-Mason book, though also interesting to students, should if it is successful be indispensable, too, for experienced geologists who have an interest in the background of their science.

This book begins with a selection from Leonardo da Vinci, once artist and craftsman but currently a hero in scientific originality. Leonardo died early in the Sixteenth Century. The book ends with Van Hise on Rock Flowage, after breaking the rules by including a passage about the Planetesimal Hypothesis that Professor Chamberlin published in 1904. Otherwise all the passages included were published before 1900, and all were written by men no longer living. One additional limitation no doubt made a decision more easy in certain cases, though it sounds odd at first: if of two excerpts of nearly the same worth one was judged to be less widely available in ordinary geological libraries in the United States than the other, that one was given the preference.

Upon reading the Source Book instead of merely speculating about it I find myself amazed that so many excellent books and articles are fairly represented by such relatively short extracts; and further that the editors have hunted up so many illuminating passages that an ordinary dabbler in such subjects can have missed completely before. In its usefulness to all readers interested in the history of geology, in fact, this new source book challenges comparison with Professor Adams' *Birth and Development of the Geological Sciences*. The two books supplement each other very well, too, in spite of the difference in the periods they cover. Together they should go far to assist coming generations of students to be better geological scholars than their immediate predecessors were.

As already suggested, no source book could possibly please everybody. The one under review is naturally no exception. By way of illustration, I can not help feeling aggrieved that Oppel was passed up while the estimable but uninspired George Perkins Marsh was included. Oppel might conceivably

[1] Chief geologist, The Texas Company (California). Manuscript received, July, 1939.

be omitted by a geologic historian with a strong anti-stratigraphic bias but how should it happen that two such historians chanced to collaborate? Whatever faults Oppel's zones may have, I find it hard to differ from Arkell in believing that they constitute the most useful stratigraphic tool ever devised. Fortunately, passages of the type I am advocating may be found, though not translated, in Kleinpell's *Miocene Stratigraphy of California.*

It is perhaps worth noting here, as I have already done in my review of Adams' *Birth and Development of the Geological Sciences,* the omission from consideration of von Hoff, whom many German writers seem to consider an earlier and perhaps greater Lyell. Instead of continuing with such mild criticisms, however—and I have no serious ones to offer—it may be just as well to stop here with congratulations to editors and publishers on the successful completion of what must have been a very difficult task.

PALAEOZOIC FORMATIONS IN THE LIGHT OF THE PULSATION THEORY, BY AMADEUS W. GRABAU

REVIEW BY R. D. REED[1]
Los Angeles, California

Palaeozoic Formations in the Light of the Pulsation Theory, by Amadeus W. Grabau. Vol. IV. *Ordovician Pulsation.* Part 1. *Ordovician Formations of the Caledonian Geosyncline, with a Review and Summary of the Skiddavian Pulsation System.* 942 pp., 67 text figs., 13 tables. Henri Vetch, Peking (1938). The French Bookstore, Peking, China. Price: Chinese, $15; U.S., $5.50; Great Britain, 20/—, postpaid.

At the International Geological Congress in 1933 Professor Grabau presented a brief but striking summary of a theory, new at that time, which he called the "Pulsation Theory." In considerably expanded form the substance of this talk was published later as "Oscillation or Pulsation," pp. 539–53 of Volume I of the International Geological Congress, Report of the XVI Session, 1936. The author begins with an argument against the oscillation theory of Haarmann which, he says, "postulates contemporary up and down movements of land masses as the primary phenomenon of tectogenesis." Grabau believes, on the other hand, that a rhythmic rise and fall of sea-level is of primary significance, though land movements may cause important secondary effects. In support of his belief in universal pulsations he next reviews the Paleozoic systems and finally presents his views diagrammatically; he concludes that his interpulsation periods have a remarkable tendency to coincide with Professor Stille's orogenic phases.

In the discussion of Grabau's talk, Stille agreed with the idea that some transgressions and regressions are worldwide but chose to look upon tectonic processes as a more probable cause than changes of sea-level. Grabau answered:

> But I question the probability that a tectonic disturbance, as recorded in a continent, would affect the entire world at the same time, so as to cause pulsations. Rather I should expect such tectonic effects to be local, . . . Worldwide, simultaneous pulsations of marine advance and retreat must be caused by changes within the ocean basins. These changes are tectonic in the largest sense of the word but are to be distinguished from local foldings of sediments.

[1] Chief geologist, The Texas Company (California). Manuscript received, July 21, 1939.

Until the matter is discussed in greater detail, we may perhaps assume that Grabau thinks of foldings as local and as unrelated to his pulsations, in spite of the suggestion carried by his Figure 1 in the 1936 paper already cited; whereas Stille believes that foldings affect similar areas simultaneously and are somehow related to the pulsations as well. In the volume under review there are a few sentences of argument devoted to the subject. Grabau still seems convinced that geosynclinal foldings and shallowings do not affect all geosynclines contemporaneously and therefore—or is it therefore?—that folds of the type we can study in mountainous areas are not closely related in origin to transgressions and regressions of the sea. He thinks it possible, nevertheless, that "periodic expansion of the suboceanic floor can take place" (p. 10) and thus take care of everything nicely. Just why this periodic expansion should not alternate with periodic contraction in a series of processes that Stille would consider purely tectonic is not evident. The question becomes particularly puzzling if it is considered in connection with a series of earth expansions and contractions like those suggested by Bucher in his latest discussion of the subject.[2]

Inasmuch as the volume under review is only one of an extensive series, too much attention should not be drawn to the briefness of the argument for the Pulsation Theory. The nature of the reader's difficulty will be evident, however, from a summary of the subjects treated in Chapter I, which contains all the general discussion of pulsations that is allotted to this volume. The chapter is 47 pages long. It opens with an explanation of what was wrong with the author's classification of Upper Cambrian and Lower Ordovician formaitons in his earlier volumes;[3] introduces the new Skiddavian Pulsation System (more or less related to the Lower Ordovician Skiddaw or Skiddavian Series of Great Britain); discusses the relation of Ordovician to the earlier Cambrian geosynclines, the complexity of American Ordovician type sections and the apparent greater simplicity of those of Europe. Next come two or three pages —all there are—devoted to such matters as deformation and pulsation. They are followed by a brief attempt to place vulcanism where it belongs in the pulsation cycle but this subject gives way very quickly to a simplification of the geosynclinal problem. Next the author abstracts an earlier paper in which he presented his formidable polar control theory, which is intended to account for the evolution of Pangaea and Panthalassa and for many curious things that have happened to them during geologic time. On pages 18–38, he summarizes his new series of Paleozoic systems—they are "pulsation" systems, of course, and seem to be rapidly increasing in number—and gives in some detail the reasons for abolishing Stille's names for orogenic periods and for adopting new ones that are supposed to be more easily remembered. They consist of such compounds as George-oric, Acad-oric, Skidd-oric, and Sild-oric. The whole Paleozoic has either 12 or 13 of them (Table II, pp. 26–27), which are defined and characterized on pages 28–38. After two or three pages about "confirmatory studies" comes a six-page table of graptolite zones which ends with the chapter on page 47. The tectonic discussion, I mean to imply, is a bit crowded in this volume.

In chapters II–XXI, pp. 48–792, Grabau discusses in considerable detail

[2] W. H. Bucher, "Deformation of the Earth's Crust," *Bull. Geol. Soc. America*, Vol. 50 (1939), pp. 421–32, esp. p. 428.

[3] See review by Byron N. Cooper, this *Bulletin*, Vol. 22 (1938), pp. 934–36.

the Ordovician sections of much of Europe, and explains how the various strata and contacts of all these sections fit the Pulsation Theory. Except to readers so steeped in European stratigraphy as to recall instantly where the Tremadocian is placed, by whom and why, or to be greatly interested in the stratigraphic position and faunal contents of the lower *Didymograptus* shale in the Oslo region, many parts of these chapters are likely to prove difficult or at least uninteresting reading. They are sufficiently well illustrated, however, so that even an examination of the many stratigraphic and structure sections is instructive and interesting. In order to secure a preliminary idea as to just what the author means to convey by his use of "Skiddavian and Ordovician," or "Pulsation System," and "Interpulsation Period," I found Figures 53, 56, 57, 59, and 65 particularly illuminating.

Chapter XXII is devoted to a summary table that gives the distribution of the Ordovician fossils in the Caledonian geosyncline. It is followed by a list of authors cited and referred to, a general index, an index of genera and species, and by a page of errata.

The foregoing brief summary of the contents of Grabau's new book may suggest that most of its readers are likely to be professional stratigraphers of highly specialized interests. I confess that such is my fear, but if so the fact is unfortunate. Whatever the merits of the Pulsation Theory in its present form, I suspect that many of the tectonic problems involved in it must be attacked in about the way Professor Grabau is attacking them if they are ever to be solved. We may also note in passing that the world now contains few if any other men so excellently trained as Professor Grabau to attack such problems. Hence a feeling of disappointment at finding the book so hard to read as it certainly is in spots; and even a greater feeling of disappointment at finding the argument so incompletely convincing. With work enough I suppose that any of us might eventually commit to memory the details of the various Bohemian, Polish, Baltic, Scandinavian, and British sections of the Ordovician. Unless we do something like that, however, or even if we do, can we judge adequately Grabau's success in interpreting these sections in terms of the Pulsation Theory? In order to assist us the author quotes at length from lithological and faunal descriptions by others, and otherwise tries to avoid confusing us but the result leaves something to be desired. As I look at Figure 57, for example, which shows how the Ordovician rocks of Sweden may be divided into Skiddavian and Ordovician systems separated by a Petrovian Hiatus, I feel little confidence in my ability to judge how clearly and definitely the facts force the theory. If a reader were to learn in great detail all that the text tells about these rocks, perhaps he would feel a trifle more confident; but even after that might he not find reason to prefer a very different classification if he could visit and study this section for perhaps 6 months or 6 years?

What can be done about it? Obviously, one course of action is to leave the Pulsation Theory to those geologists—if any besides Professor Grabau are interested in such things—who are deeply versed in stratigraphy, particularly in its broad regional aspects. Another, possibly, might be for Professor Grabau to improve and simplify the methods by which he presents his data and argues for his conclusions. If this course should prove practical—and certainly it seems to me that such authors as Kossmat and Gignoux have now and then succeeded in discussing regional problems related to stratigraphy and struc-

ture in a way that is easier to follow—then structural geologists and even oil geologists might be benefited by becoming interested in pulsations. Perhaps, after all, the chief trouble is that Professor Grabau drowns his readers in details. Perhaps he could—or perhaps he will somewhere in the series of volumes of which this is one—give us a few sample sections, clearly and simply drawn, with their proper relations adequately and simply shown, along with enough simple text to tell us just what the Pulsation Theory is about and just why it is true.

In the meanwhile Grabau's publications on his theory have already led Professor Umbgrove to publish[4] in English an exceptionally clear and instructive account of the earth's rhythms, with summary statements of most of the more important ideas that have been held about them since the time of Suess. Any geologist who wishes to master Grabau's books on pulsation might be well advised to begin by reading and re-reading this paper by Umbgrove and the one already cited by Bucher.

In conclusion, Grabau's pulsation books are eminently worth while merely as stratigraphic reference books. As a discussion of tectonics the volume under review is not certainly so valuable but the series as a whole may well prove to be much more so.

[4] J. H. F. Umbgrove, "On Rhythms in the History of the Earth," *Geol. Mag.*, Vol. 76 (1939), pp. 116–29.

PETROLEUM DEVELOPMENT AND TECHNOLOGY, 1939 BY A.I.M.E. PETROLEUM DIVISION

REVIEW BY STANLEY C. HEROLD[1]
Los Angeles, California

Petroleum Development and Technology, 1939, by the Petroleum Division, *Trans. Amer. Inst. Min. Met. Eng.*, Vol. 132. 625 pp., illustrated. Published by the Institute, 29 West 39th Street, New York City. Cloth. Price, $5.00 net.

The annual volume for 1939, the fourteenth of the series, contains the papers and discussions presented before the Petroleum Division at meetings held in San Antonio, Texas, October 5–7, 1938; in Los Angeles, California, October 20–21, 1938; and in New York City, February 13–16, 1939. The papers appear in full, with exceptions first in the form of abstracts for those which have appeared in trade journals, and secondly in the form of titles for those not reprinted from the Division's quarterly publication *Petroleum Technology*. In both cases the appropriate references to publications are given. The usual high standard for the material and its presentation has been maintained.

Chapter I, "Production Engineering," 7 papers, 92 pages: "Mud Technique in Iran"; "Development and Production Problems in High-Pressure Distillate Pools"; "Core Analysis"; "Bottom-Hole Measurements in Pumping Wells"; "Exploring Drill Holes by Sample-Taking Bullets"; "Effect of Acid Treatment upon Ultimate Recovery of Oil from Some Limestone Fields of Kansas," abstract; and "Decline Curve Analysis," abstract. It is clear that

[1] Consulting geologist and engineer, 811 West Seventh Street. Manuscript received, August 17, 1939.

most of these papers relate to specific engineering problems in drilling and production. Geologists will be interested particularly in core analysis and bullet samples.

Chapter II, "Engineering Research," 8 papers, 103 pages: "Significance of the Critical Phenomena in Oil and Gas Production"; "Gravitational Concentration Gradients in Static Columns of Hydrocarbon Fluids"; "Physical Properties of Hydrocarbons and Their Mixtures"; "Flow of Oil-Water Mixtures through Unconsolidated Sands"; "Effect of Pressure Reduction upon Core Saturation"; "Interfacial Tension between Water and Oil under Reservoir Conditions"; "Surface Chemistry of Clays and Shales"; and "Influence of Oil Flow on Water Content," abstract. Although these papers relate to subjects in petroleum physics and physical chemistry, the one on clays and shales has particular appeal to the geologist.

Chapter III, "Petroleum Economics," 3 papers, 34 pages: "A Design for More Effective Proration"; "Economic Equilibrium in Petroleum Refining Operations"; and "World Consumption of Petroleum and Related Fuels during 1938." The subjects of proration and consumption are indirectly of considerable interest to all petroleum geologists.

Chapter IV, "Production, Domestic and Foreign, and Reserves." This chapter contains 31 papers, 286 pages, on domestic production by states, or portions thereof, 23 papers, 80 pages, on foreign production by countries, excluding Bolivia and Japan, including U.S.S.R. as Russia, and one paper, 4 pages on an "Estimate of World Oil Reserves." This section on production is continuous from year to year and has been found in many cases to be an indispensable source of information for geologists as well as engineers. The tabulation of estimated reserves constitutes a feature of importance to many geologists.

Chapter V, "Refining," one paper, 5 pages. But few geologists attempt to follow activities in refining.

Year by year the volumes constituting *Petroleum Development and Technology* show an increasing differentiation between the specific interests of the geologist, the technologist, the physicist, the physical chemist, the economist, and the various types of engineers, who contribute to the advancement of the industry. Although but few of the above listed papers may be said to pertain definitely to matters of petroleum geology, the active geologist who aims to keep informed regarding advances in the allied sciences or technologies of petroleum will want this volume to be added to his set of the earlier issues in the same series.

RECENT PUBLICATIONS

ALBERTA

*"Development of the Turner Valley Gas and Oil Field," by Vernon Taylor. *Petrol. Technology*, Vol. 2, No. 3 (A.I.M.E., New York, August, 1939). *A.I.M.E. Tech. Pub. 1099*. 16 pp., 2 figs.

*"Preliminary Report: The Stratigraphy and Structure of Turner Valley, Alberta," by G. S. Hume. *Canada Geol. Survey Paper 39-4* (Ottawa, 1939). 19 pp., 4 maps, 5 cross sections. Price, $0.10.

AUSTRALIA

*"Some Physical Properties of the Reservoir Rock at Lakes Entrance,"

by I. C. H. Croll. *Mining and Geological Jour.*, Vol. 2, No. 1 (Melbourne, Victoria, July, 1939), pp. 61–65; 2 figs.

BRAZIL

*"Northeastern Oil Fields." *Divisão de Fomento de Produção Mineral Avulso 41* (Rio de Janeiro, 1939). 12 articles from *Mineração e Metalurgia*, No. 18 (1939). 127 pp., illustrations. In Portuguese.

*"Petroleum Resources of Bahia, Brazil," by Wilhelm Kegel. *Petrol Zeit.*, Vol. 35, No. 32 (Berlin, August 15, 1939), pp. 593–95; 2 figs. In German.

BULGARIA

*"How Are the Oil Prospects of Bulgaria To Be Judged?" by H. J. Fabian. *Petrol. Zeit.*, Vol. 35, No. 27 (Berlin, July 5, 1939), pp. 477–81; 4 figs. In German.

CALIFORNIA

*"A Résumé of the Application of Gravel Packing to Oil Wells in California," by W. A. Clark. *Petrol. Technology*, Vol. 2, No. 3 (A.I.M.E., New York, August, 1939). *A.I.M.E. Tech. Pub. 1079.* 8 pp., 3 figs.

GENERAL

Some Memories of a Palaeontologist, by William Berryman Scott. 336 pp. Frontispiece photograph of the author. 6×9 inches. Cloth. Princeton University Press, Princeton, New Jersey (1939). Price, $3.00.

Annual Reviews of Petroleum Technology, Vol. 4 (covering 1938). "A collection of authoritative reviews of recent developments in every aspect of the technology of petroleum." 480 pp., 20 illustrations and diagrams. Cloth. The Institute of Petroleum, The Adelphi, London, W. C. 2 (1939). Price, 11 s. ($2.70).

*"The Rise of the Sial and the Origin of Volcanic Energy," by A. Rittman. *Geologie en Mijnbouw*, Vol. 1, New Ser., No. 6 (The Hague, Netherlands, June, 1939), pp. 137–46; 2 figs. In German.

Internal Constitution of the Earth, edited by Beno Gutenberg. "A physics of the earth monograph, prepared under the auspices of the National Research Council, Washington, D.C." 413 pp. 6.75×9.375 inches. McGraw-Hill Book Company, Inc. Price, $5.00.

*"Deep-Drilling Technique and Geology," by Hubert Becker. *Bohrtechniker-Zeitung*, Vol. 57, No. 6 (Vienna, June, 1939), pp. 105–12; 3 figs.

**Manual of Style for Editors, Compositors, and Proofreaders of the Oil and Gas Journal.* Prepared by Dean Trickett. 128 pp. Petroleum Publishing Company, Tulsa, Oklahoma (1939). Price, $1.00.

**Bibliography and Index of Geology Exclusive of North America*, Vol. 6, 1938, by John M. Nickles, Marie Siegrist, and Eleanor Tatge. *Geol. Soc. America Spec. Paper* (1939). 471 pp. Cloth. Outside dimensions, approx. 6.5×10 inches.

*"Visual Studies of the Flow of Air-Water Mixtures in a Vertical Pipe," by Sylvan Cromer and R. L. Huntington. *Petrol. Technology*, Vol. 2, No. 3 (A.I.M.E., New York, August, 1939). *A.I.M.E. Tech. Pub. 1080.* 10 pp., 9 figs.

*"The Economics of Overdevelopment," by John D. Gill. *Ibid.*, *A.I.M.E. Tech. Pub. 1084.* 8 pp.

*"Multistage Stabilization of Crude," by H. S. Gibson. *Ibid., A.I.M.E. Tech. Pub. 1085.* 12 pp., 5 figs.

*"Principles of Well Spacing," by Morris Muskat. *Ibid., A.I.M.E. Tech. Pub. 1086.* 15 pp., 5 figs.

**Petroleum Facts and Figures*, 6th ed. (1939). Prepared by the department of public relations, American Petroleum Institute, 50 West 50th Street., New York. "Presents a statistical and factual picture of the operations and of the services of the American petroleum industry." Foreword by Victor H. Scales. 190 pp., 6×9 inches. Paper. Price, $1.00.

*"A Theory of Mountain-Building," by David Griggs. *Amer. Jour. Sci.*, Vol. 237, No. 9 (New Haven, Connecticut, September, 1939), pp. 611–50; 16 figs.

*"Subsidence by Thrusting: the Discussion of a Hypothetical Fault," by Andrew Clawson. *Bull. Geol. Soc. America*, Vol. 50, No. 9 (New York, September 1, 1939), pp. 1381–94; 3 figs.

*"Foraminifera of Submarine Cores from the Continental Slope," by Fred B Phleger, Jr. *Ibid.*, pp. 1395–1422; 3 pls., 4 figs.

*"The Holotype of Barbatia (Acar) gradata (Broderip & Sowerby)," by Philip W. Reinhart. *Trans. San Diego Soc. Nat. Hist.*, Vol. 9, No. 10 (San Diego, California, August 31, 1939), pp. 39–46; 1 pl.

GERMANY

*"Der Untergrund der Lüneburger Heide" (The Subsurface at Lüneburger Heide, according to the Latest Drilling: Sketch of Stratigraphy and Tectonics), by W. Haack. *Inst. Erdölforschung Tech. Hochschule Hannover Metteilungen 18.* Reprinted from *Abh. Nat. Ver. Bremen*, Vol. 31, No. 2 (1939), pp. 377–407; 5 figs.

ILLINOIS

Oil and Gas Development Map of Patoka Area (Ts. 4–6 N., Rs. 1 W., and 2 E.); *Roaches* (Ts. 1–3 S., Rs. 1 W., and 2 E.); *Olney* (Ts. 4–6 N., Rs. 9 E., 14 W.); *Albion* (Ts. 1–3 S., Rs. 9 E., 14 W.). *Illinois Geol. Survey.* Scale, 2 inches = 1 mile. Blue-line prints obtainable from map agent, 305 Ceramics Building, Urbana. Price, $0.60.

MISSISSIPPI

*"Winston County Mineral Resources," by Frederic Francis Mellen and Thomas Edwin McCutcheon. *Mississippi State Geol. Survey Bull. 38* (University, 1939). 169 pp., 32 figs., 1 pl. "Oil and Gas," pp. 51–54.

*"The Glass Dome." *Mississippi State Geol. Survey Press Mem.* (University, July, 1939). 2 mim. pp., incl. structure map.

*"Structures in Warren County North of Vicksburg." *Ibid.* (August 12, 1939). 1 mim. p.

*"The Satartia Structure, Yazoo County." *Ibid.* (August 16, 1939). 2 mim. pp., incl. structure map.

MONTANA

Cut Bank-West Kevin-Border Districts. Preliminary structural contour map, Glacier, Toole, and Pondera counties. Geology by C. E. Erdmann, assisted by N. A. Davis. Scale, 1:125,000 (1 inch = nearly 2 miles); contour

interval, 100 feet. 24×33 inches. The Director of the Geological Survey, Washington, D. C., Price, $0.25.

NEW MEXICO

*"Reservoir Characteristics of the Eunice Oil Field, Lea County, New Mexico," by C. C. Anderson, H. H. Hinson, and H. J. Schroeder. *U. S. Bur. Mines Rept. Investig. 3456* (July, 1939). 15 mim. pp., 16 figs.

PERU

*"The Oil Fields of Peru," by J. E. Rossmuss. *Petrol. Zeit.*, Vol. 35, No. 32 (Berlin, August 15, 1939), pp. 581–91; 8 figs. In German.

*"Tectonics of the Petroliferous Tertiary of Northwest Peru," by H. Falke. *Ibid.*, pp. 591–92. In German.

TEXAS

*"Quaternary Stratigraphy in the Davis Mountains, Trans-Pecos Texas," by Claude C. Albritton, Jr., and Kirk Bryan. *Bull. Geol. Soc. America*, Vol. 50, No. 9 (New York, September 1, 1939), pp. 1423–74; 11 pls., 13 figs.

VENEZUELA

*"The Relationship of Structure to Petroleum Production in Eastern Venezuela," by Willard Miller. *Econ. Geol.*, Vol. 34, No. 5 (Lancaster, Pennsylvania, August, 1939), pp. 524–36; 1 fig.

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**Journal of Sedimentary Petrology* (Tulsa, Oklahoma), Vol. 9, No. 2 (August, 1939).

"The Origin of Stylolites," by B. M. Shaub

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"Sedimentary Rocks of the Niagara Gorge," by John T. Sanford

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**Journal of Paleontology* (Tulsa, Oklahoma), Vol. 13, No. 5 (September, 1939).

"*Harrisoceras*, a New Structural Type of Orthochoanitic Nautiloid," by Rousseau H. Flower.

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"A Skull of *Osteoborus validus* from the Early Middle Pliocene of Texas," by C. Stuart Johnson
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"Genotype of the Ammonite Genus *Rhacophyllites*," by Siemon Wm. Muller
"*Operculina barkeri*, New Name for *O. tuberculata* Vaughan and Cole, 1936," T. Wayland Vaughan and W. Storrs Cole

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Grand Ballroom of Stevens Hotel, Chicago, where 25th annual meeting of the Association will be held, April 10, 11, and 12, 1940.

BULLETIN OF THE AMERICAN ASSOCIATION OF PETROLEUM GEOLOGISTS
VOL. 23, NO. 10 (OCTOBER, 1939), PP. 1589-1597

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The executive committee has approved for publication the names of the following candidates for membership in the Association. This does not constitute an election but places the names before the membership at large. If any member has information bearing on the qualifications of these nominees, he should send it promptly to the Executive Committee, Box 979, Tulsa, Oklahoma. (Names of sponsors are placed beneath the name of each nominee.)

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A. I. Levorsen (1942), *chairman*, 221 Woodward Boulevard, Tulsa, Oklahoma

1940	1941	1942
Howard S. Bryant	E. Wayne Galliher	N. Wood Bass
Leslie G. Case	Ralph H. Fash	Monroe G. Cheney
W. C. Krumbein	W. S. W. Kew	Ronald K. DeFord
Eugene McDermott	John C. Miller	Winthrop P. Haynes
C. V. Millikan	D. Perry Olcott	Ross L. Heaton
Gayle Scott	Ben H. Parker	Bela Hubbard
E. H. Sellards	Wendell P. Rand	Philip B. King
Theron Wasson	F. W. Rolshausen	T. E. Weirich

GEOLOGIC NAMES AND CORRELATIONS COMMITTEE

John G. Bartram (1942), *chairman*, Stanolind Oil and Gas Company, Tulsa, Oklahoma

1940	1941	1942
Philip K. Cochran	Monroe G. Cheney	John E. Adams
Glenn S. Dille	Robert H. Dott	Gentry Kidd
Benjamin F. Hake	Harold N. Hickey	Hugh D. Miser
R. M. Kleinpell	Merle C. Israelsky	Raymond C. Moore
C. W. Tomlinson	Walter K. Link	

PERMIAN SUB-COMMITTEE

C. W. Tomlinson (1940), *chairman*, 509 Simpson Building, Ardmore, Oklahoma

1941	1942
Monroe G. Cheney	John E. Adams
Robert H. Dott	Raymond C. Moore

COMMITTEE ON APPLICATIONS OF GEOLOGY

Carroll E. Dobbin (1942), *chairman*, U. S. Geological Survey, 224 Custom House, Denver, Colorado

J. Clarence Karcher (1942), *vice-chairman representing geophysics*, 406 Continental Building, Dallas, Texas

Carey Croneis (1942), *vice-chairman representing paleontology*, Walker Museum, University of Chicago, Chicago, Illinois

1940	1941	1942
H. S. McQueen	Hal P. Bybee	Luther E. Kennedy
B. B. Weatherby	Henry C. Cortes	Chalmer J. Roy
	E. E. Rosaire	Earl A. Trager
	Harold W. Hoots	

COMMITTEE STUDYING METHODS OF ELECTING OFFICERS

Walter R. Berger, *chairman*, Trinity Building, Fort Worth, Texas

R. M. Barnes	A. R. Denison	C. E. Dobbin.

MID-YEAR MEETING

HENRY A. LEY
San Antonio, Texas

There is no mid-year meeting of the Association this year. They are not required by our Constitution, nor have they been held every year. Our first mid-year meeting convened at Denver, Colorado, in 1922; our latest one at El Paso, Texas, in 1938. Past meetings have been colorful and successful. Their technical programs have been comprehensive and the source of many important contributions to our *Bulletin*.

Past meetings were successful because they were sponsored by local districts in response to a widespread will to do among their members and spontaneous enthusiastic support. This year your executive committee found no enthusiastic sponsorship in four districts canvassed, and consequently concluded not to force a mid-year meeting.

Annual convention statistics show that not more than 30 per cent of our membership attends, even when held in regions of highest membership density. The current executive committee is inclined to believe that our local societies, singly or in combination, may improve the *esprit de corps* by arranging one or more annual field trips, as many of the societies have done for years. One or two full days could be devoted to presentation of papers. Such meetings, in our opinion, should be attended by one or more members of your national executive committee. They can readily take on the color, scope, and comprehensiveness of the national mid-year meetings.

SOCIETY OF EXPLORATION GEOPHYSICISTS

HENRY A. LEY
San Antonio, Texas

The Society of Exploration Geophysicists will not meet with the American Association of Petroleum Geologists at Chicago in 1940. This your executive committee regrets, especially since it believes that these two important arms in petroleum exploration have much in common. Correspondence between the presidents of these two groups follows.

August 18, 1939

President Henry A. Ley
American Association of Petroleum Geologists
1042 Milam Building
San Antonio, Texas

Dear President Ley:

At its last meeting the Executive Committee of the Society of Exploration Geophysicists was advised that your Association had narrowed down its choice of place for the 1940 annual meeting to St. Louis and Chicago. The oil developments of the past few years in Illinois no doubt had an important bearing on this choice and there is little doubt that the A. A. P. G. could hold a meeting at either place with every assurance that it would be a successful one. Unfortunately, we seem to have good reason to feel that this is not true of the S. E. G. By far the greater portion of our membership is engaged in field activity and to assure well attended meetings, we cannot go very far outside the area where geophysical field work is largely concentrated. For this reason we regretfully decided that if the A. A. P. G. met in St. Louis, we would also meet there and that our respective meetings would be coördinated in the usual manner, but that if the A. A. P. G. met in Chicago, we would hold our meeting separately at some place

more centrally located for the geophysicists and at a time that would permit attendance at both meetings.

In reaching this decision the idea was frequently expressed that in the future every reasonable effort should be made to hold S. E. G. annual meetings at the same time and place as those of the A. A. P. G. and it is my hope, which is shared by most, if not all of my colleagues, that a substantial majority of our future annual meetings will be joint ones.

The decision to hold our 1940 annual meeting at a time and place different from that chosen by the A. A. P. G. for its annual meetings must not be regarded as evidence of conflicting interests, except only that we doubt very seriously whether S. E. G. can hold a meeting well attended by its members in Chicago. For that reason, and for it only, we will hold our annual meeting probably in one of the oil centers of the southwest. When definite plans have been made, we expect to extend a personal invitation to you to attend our meetings and the Society will welcome the attendance of any members of the A. A. P. G. who may be interested.

Yours very truly
(Signed) E. A. ECKHARDT, president
Society of Exploration Geophysicists

EAE:MS:mw

September 6, 1939

ANNUAL MEETING 1940

President E. A. Eckhardt
Society of Exploration Geophysicists
P. O. Box 2038
Pittsburgh, Pennsylvania

Dear President Eckhardt:

The American Association of Petroleum Geologists regrets the decision of the Executive Committee of the Society of Exploration Geophysicists not to meet with us in 1940 at Chicago.

This Association and the Society, of which you are president, are important factors in petroleum exploration. Both, in my opinion, will be called upon by our national economy to accelerate their activities as time goes on. Both groups, in my opinion, are destined to be long enduring, and of increasing importance in petroleum exploration. It is, therefore, a pleasure to note the cordiality of your letter, and the expressed hope "that in the future every reasonable effort should be made to hold S. E. G., annual meetings at the same time and place as those of the A. A. P. G. . . . "

Whatever place you select, the A. A. P. G. extends most sincere wishes for a successful and well attended S. E. G. annual meeting. We hope that many of your members will attend our Chicago meeting where they will be cordially welcomed.

Sincerely,
(Signed) HENRY A. LEY

HAL:mw

PERMIAN VOLUME[1]

RONALD K. DEFORD[2]
Midland, Texas

HISTORY OF THE IDEA

At the mid-year meeting in El Paso, Texas, September–October, 1938, the well ordered technical program was a successful summary of the geology of West Texas and New Mexico. Regional cross sections, introductory papers, papers on pre-Permian geology, and well selected field trips served to introduce the main subject of the meeting, which was the geology of the Permian system in the West Texas-New Mexico Permian basin.

[1] Manuscript received, September 8, 1939.

[2] Editor, Permian volume. Postoffice Box 865.

The stimulus of the successful program was evident at the luncheon meeting of the Association's research committee, where Raymond C. Moore proposed that the Association sponsor and publish a volume on the geology of the Permian system in the western interior United States.

In subsequent months through correspondence and interviews A. I. Levorsen, chairman of the research committee, investigated the feasibility of such a project and gathered preliminary plans for its execution. He presented his results to the executive committee of the Association at the 24th annual meeting in Oklahoma City, March, 1939. The executive committee voted to "approve the research committee's project of a symposium on the Permian west of the Mississippi River," and appointed Ronald K. DeFord editor and Raymond C. Moore associate editor. E. Russell Lloyd has since been appointed associate editor. Meanwhile the impetus of the mid-year meeting has not died down, but studies of the Permian, fundamental to a Permian volume, have continued. Authors and editors have been at work to bring to publication the papers read at El Paso. A number of these are ready and will probably appear in the January, 1940, *Bulletin* as Part I of the "West Texas-New Mexico Symposium."

J. T. Richards, chairman of the technical program committee of the Oklahoma City annual meeting, divided his program into sections one of which was devoted to the Permian. The excellent "Anadarko Basin Field Trip" to the Whitehorse and El Reno outcrops preceded the meeting. The program of the Permian session was headed by Carl O. Dunbar, who read a paper on "The Permian System: Its Classification and Correlation." Sherwood Buckstaff gave his paper, "The Permian Sediments of Oklahoma." In preparing this paper Buckstaff became the center of considerable correspondence about the proper subdivision of the Permian system into series. The program also included George H. Norton's definitive paper on the Kansas red beds, and paleontologic papers by Carl O. Dunbar on Permian fusulines, A. K. Miller on Permian ammonoids, and Norman D. Newell and others on the fauna of the Whitehorse.

An evening "round-table discussion" (more accurately, an open meeting) at Oklahoma City carried forward the discussion of Permian problems and classification. The proposed subdivision[3] of the Permian system into series based on the typical section in and around the Delaware basin grew directly out of the "round table." The first draft was prepared in Midland, Texas, a week later and subsequently underwent a wide distribution and revision.

In May, 1939, John G. Bartram, chairman of the Association's geologic names and correlations committee, appointed a Permian subcommittee consisting of C. W. Tomlinson, chairman, John Emery Adams, M. G. Cheney, Robert H. Dott, and Raymond C. Moore, "to prepare a digest and recommendations for the classification and nomenclature of Permian rocks of the United States." The subcommittee's first studies were brought to a focus by an all-day meeting in Fort Worth on June 17. There the entire membership agreed on a preliminary report that has since been widely circulated for criticism and correction to local geological societies and interested individual geologists. Copies may be obtained from C. W. Tomlinson, Simpson Building, Ardmore, Oklahoma.

[3] John Emery Adams, M. G. Cheney, Ronald K. DeFord, Robert I. Dickey, Carl O. Dunbar, John M. Hills, Robert E. King, E. Russell Lloyd, A. K. Miller, and C. E. Needham, "Standard Permian Section of North America," *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 23, No. 11 (November, 1939).

This preliminary report recommends that the Permian be recognized as a system and gives reasons for the recommendation. It defines the terms *system*, *series*, *group*, and outlines the characteristics of a suitable standard section. It recommends the section of the "Delaware basin and its bordering uplifts" as the most suitable standard American section of the Permian. It proposes certain lower and upper boundaries for the Permian and recommends the subdivision of the Permian system into four series named Wolfcamp, Leonard, Guadalupe, and Ochoa, as proposed in the note by John Emery Adams and others, previously mentioned.

The wide circulation that this preliminary report has had and the warm discussion it has elicited will not only aid the subcommittee to prepare a well considered final report that will serve as a semi-official standard of reference but will also further stimulate widespread study of the problems of the Permian that will prove valuable as ground work for the Permian volume.

Carl O. Dunbar is chairman of the National Research Council's committee on stratigraphy and also chairman of the Council's subcommittee on the Permian. The committee on stratigraphy has nearly completed correlation charts for all the systems of the geologic column; this has been a work of several years. The original plan contemplated that each of these charts would be followed by a volume for each system giving a summary of the stratigraphy. Carl O. Dunbar has generously said that he would withhold his preliminary plans and give the right of way to the Association's Permian volume. The National Research Council's correlation chart on the Permian, soon to be published, will be another forward step toward a better history of the Permian.

Mention must be made of the whole-hearted coöperation of the United States Geological Survey. Philip B. King has been in the midst of the plans and discussions. His forthcoming paper on the West Texas Permian will be fundamental to subsequent work. At the Oklahoma City meeting Arthur A. Baker and James Steele Williams described the little-known but surprisingly thick Permian section near Provo, Utah. The sagacious advice of Hugh D. Miser and the philosophical discussions of James Steele Williams have been and will be invaluable. Other members of the Survey have been unselfishly coöperative whenever called upon.

All this can be considered the pre-history of the Permian volume, the story of how the idea grew. There follows an outline of the plan. This is preliminary, and it will be developed and modified in the execution.

PLAN

The purpose of the Permian volume is to reconstruct the Permian history of the western interior United States and to correlate the geologic history of this part of the Permian system with its present economic importance. So large a purpose can not be realized by next month or next spring. The probable publication date is 4 or 5 years in the future.

The Permian volume will be a publication of the American Association of Petroleum Geologists. A large percentage of the data on which it must be based will necessarily come from petroleum geologists, and petroleum geologists are the readers whom the authors should have first in mind in planning and writing this volume.

The proposed plan is first to reconstruct the geologic history; then to develop its connection with economics in a final section of the volume, which will show the fundamental relation of Permian stratigraphy, structure, and paleogeology to such important economic factors in the past, present, and future history of the United States as the production of oil and potash.

Now, geologic history involves such interesting subjects as paleogeography, sedimentation, the origin of oil. But a geologist's conception of the history of any geologic period can be derived only from the study of geologic data gathered in the field. There are three types of information relative to the *geologic* parts of the volume, which may be classed as primary, secondary, and tertiary.

1. The primary facts. These are the measured vertical sections, and facts about the characteristics of the rocks, their observed gradations and contained fossils.

2. The secondary data. These are the correlations of Permian formations derived from study of the primary facts.

3. The tertiary syntheses. These are the reconstructions of Permian history derived entirely from scientific study of the other two types of information. Paleogeography and sedimentation belong here.

Although the distinction between the primary facts of measurement and the secondary data of correlation should be kept always in mind, and during composition the correlations should be continually re-verified, the presentation of these two types of information forms a natural unit, commonly found in geologic papers under the heading "Stratigraphy." They will be treated together in the first part of the Permian volume, which will thus consist of three major parts: I. Stratigraphy; II. Geologic History; III. Economics. The present plan is to leave the most important parts, the geologic history and the economics, pretty much to the future and to lay the foundation now by concentrating on the measured sections and their correlation. These can be presented partly by reference to other publications and partly by original summary in the first part of the volume.

The first step in preparing this summary will be to cover the region with a network of measured sections. In the West Texas-New Mexico district, to take a concrete example, such a "measured section" will not be a single measurement and description of the outcrop on a lone mountainside, nor will it be the sample log of a single well, but it will be compound. It will consist, for example, of a group of three or four sample logs of wells so located as to constitute a representative cross section of a typical unit of the region. These graphic logs will be shown on one page of the volume, evenly spaced without regard to horizontal distance between wells, and the relevant written matter will be on the page facing the diagram. Correlation lines will connect the logs.

The plan is to have in Midland, Abilene, Wichita Falls, Amarillo, Oklahoma, Kansas, and elsewhere local chairmen in charge of committees. The work of the committees will be to choose the proper network of sections, to divide among many geologists the work of preparing the individual logs and single sections, to combine these into the compound form and draw the necessary correlation lines, and to coöperate with the other committees in correlating the compound sections one with another.

Paleontologic evidence will play an essential part in the long-range correlations, and the committees will seek the aid of all informed paleontologists.

A summary of the paleontology of the Permian, with special emphasis on index fossils, is also considered desirable.

When the work on the foundation is well under way, it will be time enough to consider in detail how to present the different aspects of Permian history.

Comments, advice, and criticism are earnestly solicited. Write to the editor now or at any future time about anything you may have in mind.

SPEAKERS SERVICE

CHALMER J. ROY
University, Louisiana

The executive committee, acting on the suggestion in the report of the research committee for last year, has established a speakers service as a part of the committee on applications of geology.

The research committee has found that a number of universities would like to secure speakers from the membership of the Association. These speakers may be wanted for a special occasion to address a general audience but in most instances the speaker will give one or more lectures to students in geology. In schools having large and active geology departments the lectures may be on highly technical subjects whereas schools with little or no geology will desire more general subject matter. Ordinarily no fee is available for such speakers but in most instances expenses will be paid.

Also it seems probable that many civic organizations will avail themselves of this service. Clubs of many types desire speakers on geologic subjects for luncheon, afternoon, or evening meetings. Here again the funds available will permit only the payment of the speaker's expenses in most instances. In this work the speakers will have an opportunity to create a greater public interest in geology and, even more important, see that the public is accurately informed on various aspects of petroleum geology.

Professor Chalmer J. Roy of Louisiana State University has been appointed a member of the committee on applications of geology and is in charge of the speakers service. Any member of the Association willing to devote time to this work should write Professor Roy giving full details about subject matter on which the member is prepared to speak; fee expected, in addition to expenses, if any; and times at which member will be available. It is hoped that members in all parts of the country will coöperate so that speakers may be readily available wherever desired.

BULLETIN OF THE AMERICAN ASSOCIATION OF PETROLEUM GEOLOGISTS
VOL. 23, NO. 10 (OCTOBER, 1939), PP. 1598-1602

AT HOME AND ABROAD

CURRENT NEWS AND PERSONAL ITEMS OF THE PROFESSION

JOHN R. DODGE, head of the division of petroleum engineering at the University of Southern California, Los Angeles, announces a new course in petroleum geology, listed as "Geology 157," to be given by STANLEY HEROLD, beginning September 29. The course in mathematical analysis of petroleum problems, listed as "Petroleum Engineering 121," also given by Stanley Herold, will begin its second quarter, September 27.

HENRY SCHWEER, consulting geologist of Oklahoma City, has accepted a position with the Socony Vacuum Oil Company and may be addressed at Apartado 246, Caracas, Venezuela.

O. S. HERVEY is doing core analysis work in the chemistry department of the Sun Oil Company, Dallas, Texas.

MORGAN E. MCCASKEY, recently returned from Washington and New York, announces opening an office at 211-12 Praetorian Building, Dallas, Texas, to serve his north-central Texas clientele.

The Appalachian Geological Society, Charleston, West Virginia, held its first fall meeting at the Kanawha Hotel, September 11. LEO RANNEY spoke on "The First Horizontal Well in the Cow Run Sand near McConnellsville, Ohio."

GUY E. MILLER, of the Shell Oil Company's geological department at Bakersfield, California, has been appointed division geologist of the San Joaquin division.

RALPH D. REED, of Los Angeles, chief geologist of The Texas Company (California), vice-president of the Association in 1930, editor of the *Bulletin* in 1932, president in 1936, author of *Geology of California* (1933), senior author of *Structural Evolution of California* (1936), and otherwise generous contributor to the prestige of the *Bulletin* and the Association, was elected honorary member of the Association by the executive committee in session at Tulsa, Oklahoma, September 16.

H. W. STRALEY, III, formerly at Chapel Hill, North Carolina, may be addressed at Box 363, Waco, Texas.

C. L. MORGAN is district geologist for the Lion Oil Refining Company at Jackson, Mississippi. His address is 228 Mt. Vernon.

W. P. JENNY, consulting geologist and geophysicist, has returned to 907 Sterling Building, Houston, Texas, after several months in Europe.

O. E. STONER, geologist for The Major Oil Company of Texas, with offices in the Court Arcade Building, Tulsa, Oklahoma, is at 826 Ravenswood, Evansville, Indiana.

The American Society of Photogrammetry presented the following papers at its semi-annual meeting in San Antonio, Texas, September 26–28: "Photogrammetry—the Science of Measuring Photographs," by W. SCHERMERHORN, Delft, Holland; "Photogrammetry-Radiology," by DALTON RICHARDSON, Austin, Texas; "Making Aerial Photographs," by VIRGIL KAUFFMAN, Philadelphia, Pennsylvania; "The Construction and Performance of Zeiss Aerial Cameras," by GUSTAV HESS, Jena, Germany; "Interpretation of Aerial Photographs," by FRANK MELTON, Norman, Oklahoma; "Mosaics and Planimetric Maps," by LOUIS A. WOODWARD, U. S. Soil Conservation Service; "Topographic and Cadastral Mapping by the Brazos District," by ERIC HAQUINIUS and G. C. MORRIS; "The Uses of Aerial Photogrammetry in the Petroleum Industry," by G. W. HERZOG, Houston, Texas; "The Use of Aerial Photographs and Maps by the Texas Highway Department," by JULIAN MONTGOMERY; "The Aerial Photographic and Photogrammetry Activities of the Federal Government," by MARSHALL S. WRIGHT; "Requirements for Completion of Modern Mapping in Texas," by J. C. CARPENTER.

JEROME B. BURNETT may be addressed in care of the Vacuum Oil Company, Pty., Ltd., 29 Market Street, Melbourne, Australia.

A Cambro-Ordovician symposium sponsored by Sigma Gamma Epsilon, honory geologic fraternity, will be held at Norman, Oklahoma, on the evening of November 4, under the direction of ROBERT H. DOTT, director of the Oklahoma Geological Survey. CHARLES E. DECKER, professor of paleontology at the University, will be chairman of the program. The customary banquet will be held in the early evening following the Iowa State-Oklahoma University homecoming football game.

The expedition to the Pacific Islands, under the auspices of the National Geographic Society and the University of Virginia with the coöperation of the United States Coast Guard, which left San Francisco last month on the Coast Guard cutter *Hamilton*, is under the leadership of Professor WILBUR A. NELSON, of the University of Virginia department of geology. Cores of mud will be taken from the ocean bottom, gravity and magnetic investigations will be made, and sea life will be studied.

ROGER REVELLE, of the Scripps Institution of Oceanography of the University of California, is in charge of the cruise of the research vessel *E. W. Scripps*, which left San Diego in August for the study of ocean currents and undersea strata from San Diego to Santa Barbara, California.

GEORGE B. SOMERS, of the Deutsche-Vacuum Oel Company, Hamburg, Germany, has returned to the United States. His address is 721 Browder Street, Dallas, Texas.

W. E. BAKKE has moved from Owensboro, Kentucky, to 254 College Avenue, Holland, Michigan, where he is in business for himself.

D. L. BLACKSTONE, JR., recently at St. Joseph, Missouri, has resigned from the Carter Oil Company and accepted an assistant professorship at the University of Missouri.

F. W. ROLSHAUSEN, of the Humble Oil and Refining Company, spoke before the Houston Geological Society, September 14, on "A Few Common Fossil Horizons of the Gulf Coast."

JOSIAH TAYLOR, of the General Geophysical Company, has been transferred from the Bakersfield office to Houston, Texas.

The West Texas Geological Society annual fall field trip will be held this year in the Llano-Burnet region, immediately following the annual convention of Texas Academy of Science, meeting at the University of Texas, Austin, Texas, November 8, 9, and 10, 1939. HAL P. BYBEE, chairman of the department of geology of the University of Texas, recently conferred with officers and members of the West Texas Geological Society regarding details of the field trip. Present plans call for West Texas and other geologists, not attending the convention, to meet at Brady, Texas, Friday night, November 10. They will be joined at Brady, Saturday morning, November 11, by members of the Texas Academy of Science from Austin, for that day's field trip, under competent guides, through part of the Llano-Burnet area. Headquarters, Saturday night, will be Austin, Texas, where the visiting geologists and the Academy members will attend a dinner at the University in honor of a special speaker. Sunday morning, November 12, the field trip will continue from Austin, through the remaining part of the Llano-Burnet area, breaking up, Sunday evening, within a few hours' drive of West Texas, Austin, and other points. Geologists making this field trip will be given a special opportunity to study pre-Pennsylvanian stratigraphy. Recent flush production obtained from the Ellenburger limestone, Lower Ordovician, in Pecos County, Texas, has aroused new interest in detailed stratigraphic study of the Ellenburger section itself. Officers of the West Texas Geological Society, Midland, Texas, an affiliate of the American Association of Petroleum Geologists, are: president, BERTE R. HAIGH, University Lands; vice-president, W. C. FRITZ, Shell Oil Company; secretary-treasurer, J. E. SIMMONS, Continental Oil Company.

FRANK A. HERALD, who recently resigned his position with the Oil and Gas Unit of the Securities and Exchange Commission at Tulsa, Oklahoma, has accepted the position of chief engineer with the Independent Oil Producers Equity Association, 818 Scarbrough Building, Austin, Texas.

S. D. BUTCHER, formerly in charge of the Houston district for the Midstates Oil Corporation, is now located at the Commodore Hotel, Wichita, Kansas.

JOHN W. BRICE, of the Standard Oil Company (New Jersey), has moved from New York to Caracas, Venezuela, to be executive assistant to H. E. Linam, president of the Standard Oil Company of Venezuela.

G. MOSES KNEBEL is now on the executive staff of the producing department of the Standard Oil Company (New Jersey) at New York City, having been transferred from Caripito, Venezuela.

The annual meeting and field trip of the South Texas Geological Society is being held, October 20–23. Those taking the field trip assemble at Laredo, Thursday night, October 19, and leave, Friday morning, October 20, to cover the territory between Laredo and Sam Fordyce, at which latter point the

field trip ends for the day and the members proceed to Brownsville to spend the night. The Plaza Hotel at Laredo and the El Jardin Hotel at Brownsville, Texas, are the stopping places. The technical sessions, in charge of Joseph M. Dawson, chairman of the program committee, are held in the El Jardin Hotel, Brownsville, Saturday, October 21, during the day. A second field trip, Sunday morning, October 22, led by W. ARMSTRONG PRICE, covers the territory between Brownsville and Mission, Texas. I. K. HOWETH, 2109 Alamo National Building, San Antonio, and L. B. HERRING, 636 Nixon Building, Corpus Christi, Texas, are in charge of arrangements. WILLIS STORM is president and ROBERT N. KOLM is secretary-treasurer of the society. The following papers are on the technical program.

1. Geological Workshops and Showrooms—HENRY LEY, president, American Association of Petroleum Geologists, San Antonio
2. Revision of a Portion of the Areal Geology along the Rio Grande, Southeast of Laredo—FRITH C. OWENS, Nueces Royalty Company, Corpus Christi
3. Samfordyce Field, Hidalgo and Starr Counties, Texas—E. L. EARL, Fohs Oil Company, and FREDERICK W. MUELLER, Skelly Oil Company, Houston
4. Economics and Evaluation of Oil and Gas Fields of South Texas—L. B. HERRING, Corpus Christi
5. Commercial Production of Synthetic Products from Natural Gas—HAROLD M. SMITH, U. S. Bureau of Mines, Bartlesville, Oklahoma
6. Soil Analysis with Particular Application to South Texas—EUGENE MCDERMOTT, Geophysical Service, Inc., Dallas
7. Physiographic Mapping of Quaternary Formations in the Rio Grande Delta—W. ARMSTRONG PRICE, Corpus Christi
8. Oil and Gas Fields of the Rio Grande Valley of Texas—L. C. SMITH, Sun Oil Company, Dallas

The Fort Worth Geological Society opened its fall program, September 25, with an address by CHARLES F. ROESER, president of the Independent Petroleum Association of America, on the subject "Current Conditions in the Oil Industry."

MALVIN G. HOFFMAN, chief geologist of the Midco Oil Corporation, Tulsa, addressed the Shawnee Geological Society at Shawnee, Oklahoma, September 25, on the subject, "The Rôle of Isostasy in Mountain Building."

ALVA C. ELLISOR, research paleontologist with the Humble Oil and Refinding Company, spoke on "Subsurface Miocene of Louisiana," before the Houston Geological Society, September 21.

LOUIS C. ROBERTS, JR., announces the opening of his consulting office at 2527 Gulf Building, Houston, Texas.

A. H. GARNER has moved from his New York Office to the First National Bank Building, Dallas, Texas.

JOHN J. RUPNIK has resigned from The Texas Company and has entered the California Institute of Technology for graduate work. His address is 105 South Catalina Avenue, Pasadena, California.

MEMBERSHIP APPLICATIONS APPROVED FOR PUBLICATION

(Continued from page 1589)

FOR ACTIVE MEMBERSHIP

Charles M. Cross, San Francisco, Calif.
Joseph A. Taff, F. A. Menken, G. D. Hanna
Herbert Richard Lovely, Budapest, Hungary
R. P. Walters, K. D. White, H. Hlauschek
Silas Frederick Shaw, San Antonio, Tex.
Joseph M. Dawson, Richard W. Camp, Hubert E. Bale

FOR ASSOCIATE MEMBERSHIP

Richard Stewart Ballantyne, Jr., Los Angeles, Calif.
Robin Willis, U. S. Grant, M. Van Couvering
Joe August Champion, Caracas, Venezuela, S. A.
R. H. Sherman, F. A. Sutton, G. F. Kaufmann
Peter H. Gardett, Los Angeles, Calif.
Dwight H. Thornburg, W. P. Winham, Art R. May
Charles Campbell Green, Jr., Houston, Tex.
William S. Pike, Jr., Frank G. Evans, Jr., Thomas L. Bailey
John Darrow Hale, Bakersfield, Calif.
Art R. May, D. E. Taylor, E. C. Simpson
Wilfred Bonno Tapper, Wichita Falls, Tex.
Hillard W. Carey, A. C. Trowbridge, A. K. Miller

FOR TRANSFER TO ACTIVE MEMBERSHIP

Eugene Melvin Baysinger, Lake Charles, La.
R. B. Grigsby, G. O. Grigsby, W. R. Canada
Owen W. Simonton, Mattoon, Ill.
Dewitt T. Ring, B. S. Ridgeway, C. W. Studt
Harvey Burton Whitaker, San Antonio, Tex.
W. W. McDonald, W. W. Harvey, Herschel H. Cooper

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L. C. MORGAN
Petroleum Engineer and Geologist

Specializing in Acid-Treating Problems

358 North Dellrose
WICHITA, KANSAS

MARVIN LEE
Consulting Petroleum Geologist
1109 Bitting Building
WICHITA, KANSAS
Office: 3-8941 *Residence:* 4-4873
GEOLOGY AND PRODUCTION PROBLEMS OF OIL AND GAS IN THE UNITED STATES
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985 Gilbert Street, Boulder
1st Vice-President - - - David B. Miller
1336 Gaylord Street
2nd Vice-President - - - Harold N. Hickey
810 U. S. National Bank Building
Secretary-Treasurer - - - - - - Ninetta Davis
224 U. S. Customs Building

Dinner meetings, first and third Mondays of each month, 6:15 P.M., Auditorium Hotel.

ILLINOIS

ILLINOIS GEOLOGICAL SOCIETY

President - - - - - - - Verner Jones
Magnolia Petroleum Company, Mattoon

Vice-President - - - - Melville W. Fuller
Carter Oil Company, Mattoon

Secretary-Treasurer - - Elmer W. Ellsworth
W. C. McBride, Inc., Centralia

Meetings will be announced.

KANSAS

KANSAS GEOLOGICAL SOCIETY

WICHITA, KANSAS

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Atlantic Refining Company
Vice-President - - - - Thomas H. Allan
Consulting Geologist
Secretary-Treasurer - - - - E. Gail Carpenter
Consulting Geologist
Manager of Well Log Bureau - Harvel E. White

Regular Meetings: 7:30 P.M., Allis Hotel, first Tuesday of each month. Visitors cordially welcomed.

The Society sponsors the Kansas Well Log Bureau which is located at 412 Union National Bank Building.

LOUISIANA

THE SHREVEPORT GEOLOGICAL SOCIETY

SHREVEPORT, LOUISIANA

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Union Producing Company
Vice-President - - - - - - - - L. S. Harlowe
Grogan Oil Company
Secretary-Treasurer - - - - - - E. F. Miller
Oliphant Oil Corp., 911 Commercial Bank Bldg.

Meets the first Friday of every month, 7:30 P.M., Civil Courts Room, Caddo Parish Court House. Special dinner meetings by announcement.

SOUTH LOUISIANA GEOLOGICAL SOCIETY

LAKE CHARLES, LOUISIANA

President - - - - - - - Dean F. Metts
Humble Oil & Refining Co., Crowley, La.
Vice-President - - - - H. E. McGlasson
Stanolind Oil and Gas Company
Secretary - - - - - - G. O. Grigsby
Stanolind Oil and Gas Company
Treasurer - - - - - - - Baker Hoskins
Shell Oil Company, Inc.

Meetings: Luncheon 1st Wednesday at Noon (12:00) and business meeting third Tuesday of each month at 7.00 P.M. at the Majestic Hotel. Visiting geologists are welcome.

MICHIGAN

MICHIGAN GEOLOGICAL SOCIETY

President - - - - - - - Carl C. Addison
The Pure Oil Company, Saginaw

Vice-President - - - - - Jed B. Maebius
Gulf Oil Corporation, Saginaw

Secretary-Treasurer - - - - R. P. Grant
Michigan Geological Survey, Lansing

Business Manager - - - - Helen Martin
Michigan Geological Survey

Meetings: Monthly dinner meetings rotating between Saginaw, Mt. Pleasant, and Lansing. Informal dress.

OKLAHOMA

ARDMORE GEOLOGICAL SOCIETY
ARDMORE, OKLAHOMA

President - - - - - - - - - - Don L. Hyatt
Carter Oil Company

Vice-President - - - - - - - - - J. P. Gill
Sinclair Prairie Oil Company

Secretary-Treasurer - - - W. Morris Guthrey
The Texas Company

Meetings: First Tuesday of each month, from October to May, inclusive, at 7:30 P.M., Dornick Hills Country Club.

OKLAHOMA CITY GEOLOGICAL SOCIETY
OKLAHOMA CITY, OKLAHOMA

President - - - - - - - - - Dan O. Howard
Oklahoma Corporation Commission

Vice-President - - - - Albert S. Clinkscales
Consulting Geologist, Colcord Building

Secretary-Treasurer - - - - - - - R. Hancock
Magnolia Petroleum Corporation

Meetings, Ninth Floor, Commerce Exchange Building: Technical Program, second Monday, each month, 8:00 P.M.; Luncheons, every Monday, 12:15 P.M.

SHAWNEE GEOLOGICAL SOCIETY
SHAWNEE, OKLAHOMA

President - - - - - Roy P. Lehman
Phillips Petroleum Company

Vice-President - - - - - J. Lawrence Muir
Amerada Petroleum Corporation

Secretary-Treasurer - - - - Tom L. Girdler, Jr.
Sinclair Prairie Oil Company

Meets the fourth Monday of each month at 8:00 P.M., at the Aldridge Hotel. Visiting geologists welcome.

THE STRATIGRAPHIC SOCIETY OF TULSA
TULSA, OKLAHOMA

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The Texas Company

Vice-President - - - - - - - L. A. Johnston
Sunray Oil Company

Secretary-Treasurer - - Constance Leatherock
Tide Water Associated Oil Company

Meetings: Second and fourth Wednesdays, each month, from October to May, inclusive, at 8:00 P.M.

TULSA GEOLOGICAL SOCIETY
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The Texas Company

Editor - - - - - - - - A. N. Murray
University of Tulsa

Associate Editor - - - - Maurice R. Teis
Homestake Companies

Meetings: First and third Mondays, each month, from October to May, inclusive, at 8:00 P.M., University of Tulsa, Tyrrell Hall Auditorium. Luncheons: Every Thursday, Michaelis Cafeteria, 507 South Boulder Avenue.

TEXAS

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DALLAS, TEXAS

President - - - - - - - - - - R. E. Rettger
Sun Oil Company

Vice-President - - - - - - W. W. Clawson
Magnolia Petroleum Company

Secretary-Treasurer - - - Henry J. Morgan, Jr.
Atlantic Refining Company

Executive Committee - - - Eugene McDermott

Meetings: Regular luncheons, first Monday of each month, 12:15 noon, Petroleum Club. Special night meetings by announcement.

EAST TEXAS GEOLOGICAL SOCIETY
TYLER, TEXAS

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Shell Oil Company, Inc.

Vice-President - - - - - - E. M. Rice
Pure Oil Company

Secretary-Treasurer - - - Frank R. Denton
Stanolind Oil and Gas Company

Meetings: Monthly and by call
Luncheons: Every Monday at 12:00 noon, Blackstone Hotel.

TEXAS

FORT WORTH GEOLOGICAL SOCIETY
FORT WORTH, TEXAS

President - - - - - - - J. Earle Brown
Consulting Geologist, Trinity Life Building

Vice-President - - - - - J. H. Markley
The Texas Company

Secretary-Treasurer - - - - Vernon Lipscomb
The Pure Oil Company

Meetings: Luncheon at noon, Worth Hotel, every Monday. Special meetings called by executive committee. Visiting geologists are welcome to all meetings.

HOUSTON GEOLOGICAL SOCIETY
HOUSTON, TEXAS

President - - - - - - - David Perry Olcott
Humble Oil and Refining Company

Vice-President - - - - - - R. A. Weingartner
Stanolind Oil and Gas Company

Secretary-Treasurer - - - Carleton D. Speed, Jr.
Speed Oil Company

Regular meetings held every Thursday at noon (12 o'clock) above Kelly's Restaurant, 910 Texas Avenue. For any particulars pertaining to the meetings write of call the secretary.

NORTH TEXAS GEOLOGICAL SOCIETY
WICHITA FALLS, TEXAS

President - - - - - - - Tom F. Petty
Humble Oil & Refining Company

Vice-President - - - - Paul E. M. Purcell
701 Hamilton Building

Secretary-Treasurer - - - Orion A. Daniel
Consulting Geologist
814 Hamilton Building

Luncheons and evening programs will be announced.

SOUTH TEXAS GEOLOGICAL SOCIETY
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President - - - - - - - - - - Willis Storm
1733 Milam Building, San Antonio

Vice-President - - - - - - - Dale L. Benson
Sinclair Prairie Oil Company, Corpus Christi

Secretary-Treasurer - - - - Robert N. Kolm
1742 Milam Building, San Antonio

Executive Committee - - - - - - E. L. Porch

Meetings: Third Friday of each month at 8 P.M. at the Petroleum Club. Luncheons every Monday noon at Petroleum Club, Alamo National Building, San Antonio, and at Plaza Hotel, Corpus Christi.

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Vice-President - - - - - - Leo Hendricks
Bureau of Economic Geology

Secretary-Treasurer - - - - - - W. C. Ikins
Univ. Texas, Dept. of Geology

Meetings: Every third Friday at 8:00 P.M. at the University of Texas, Geology Building 14.

WEST TEXAS GEOLOGICAL SOCIETY
MIDLAND, TEXAS

President - - - - - - - Berte R. Haigh
University Lands

Vice-President - - - - - - W. C. Fritz
Skelly Oil Company

Secretary-Treasurer - - - - - J. E. Simmons
Continental Oil Company

Meetings will be announced

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Ohio Fuel Gas Company
Columbus, Ohio

Secretary-Treasurer - - - Charles Brewer, Jr.
Godfrey L. Cabot, Inc., Box 348

Meetings: Second Monday, each month, at 6:30 P.M., Kanawha Hotel.

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